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Bulletin

of the

Torrey Botanical Club

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Meetings twice each month from October to May, inclusive: the first Tuesday at 8:15 P.M., at the American Museum of Natural History or at Columbia University; the third Wednesday at 3:30 P.M., in the Museum Building of the New York Botanical Garden, Bronx Park, New York, N.Y.

PUBLICATIONS

All subscriptions and other business communications relating to the publications of the Club should be addressed to the Treasurer, Mrs. R. A. Harper (mail address, Schermerhorn Hall, Columbia University, New York, N.Y.). Matters relating to advertisements and circulation should be referred to Dr. Michael Levine, Montefiore Hospital, New York, N.Y. All communications regarding exchanges should be referred to the Exchange Committee, consisting of the Librarian of the Columbia University and the Librarian of the New York Botanical Garden.

Bulletin. Established 1870. Monthly, except during July, August, and September. Price $6.00 a year; single numbers 75 cents. Of former volumes, only 24-56 can be supplied separately; certain numbers of other volumes are available, but the entire stock of some numbers has been reserved for the completion of sets. Manuscripts intended for publication in the BULLETIN should be addressed to Prof. M. A. Chrysler, Department of Botany, Rutgers University, New Brunswick, N.J. The editors may accept papers up to 20 pages in length, with illustrations and tabular matter generally not exceeding twenty per cent of that amount. Longer and more copiously illustrated papers, however, may be published if the excess pages, illustrations, and tabular matter are paid for by the contributors.

Torreya. Bimonthly, established 1901. Price, $1.00 a year. Manuscripts intended for publication in TORREYA should be addressed to Mr. George T. Hastings, Editor, 2587 Sedgwick Ave., New York, N.Y.

Memoirs. Occasional, established 1889.

Preliminary Catalogue of Anthophyta and Pteridophyta within 100 miles of New York City, 1888. Price, $1.00.

Reprints. Contributors of articles accepted for publication in the BULLETIN should order reprints, if desired, when they return galley proofs to the editor. They may be ordered through the editor from the George Banta Publishing Company, the contributor paying for all his reprints. A schedule of rates is sent with galley proof.

The published work of Elizabeth Gertrude Britton[1]

JOHN HENDLEY BARNHART

Elizabeth Gertrude Knight was born in the city of New York, 9 January 1858. Much of her childhood was spent in Cuba, but she attended school in New York, and was graduated from the Normal College there, now Hunter College, in 1875, and taught in that institution for the next ten years. She became the wife of Nathaniel Lord Britton 27 August 1885, and nearly fifty years later, 25 February 1934, she died at her home near the New York Botanical Garden. Such are the outstanding dates in the life of one who was for more than 54 years an active member of the Torrey Botanical Club, in whose publications many of her papers made their appearance.

Her life has been discussed so well by Marshall A. Howe in the Journal of the New York Botanical Garden (**35:** 97–103, with a portrait. My 1934), that it would be superfluous to repeat essentially the same data here. But it is eminently appropriate that a full statement of her published work should be placed on record in this BULLETIN, to whose pages she was long a frequent contributor, and of which she was editor during 1886, 1887, and 1888.

Mrs. Britton was for years the foremost American bryologist, and to most people her name recalled only her studies of mosses; but she was also interested in ferns and flowering plants, and in later years devoted much time to efforts for the preservation of wild flowers. The titles in the accompanying bibliography may be classified roughly as follows:

Mosses	170
Ferns	16
Flowering plants	15
Wild-flower preservation	47
Biography	4
Reviews	66
Miscellaneous	28
	346

At first it was intended to include no reviews in this list except the many in which valuable original observations were recorded, but it proved so difficult to draw the line that eventually all reviews were included that

[1] Note. It was a request of the late Doctor N. L. Britton that this bibliography be prepared and published in the Bulletin. It is proposed to issue in the near future a Britton Memorial number of the Bulletin.—Editor.

she regarded as of sufficient importance to sign with her name or initials. No doubt she actually wrote many anonymous book-notices, especially during her editorship of the BULLETIN, but the present list is believed to be a virtually complete one of the publications identifiable as her work.

1881

1. Albinism. Bull. Torrey Club **8:** 125. N 1881.

1883

2. Submersed leaves in *Limnanthemum*. Bull. Torrey Club **10:** 34. Mr 1883.
3. On the fruit of *Eustichium norvegicum* Br. Eur. Bull. Torrey Club **10:** 99, 100. *f. 1–6*. S 1883.

1884

4. Note on *Corema Conradii*. Bull. Torrey Club **11:** 116. O 1884.
5. *Salisburia adiantifolia* Smith. Bull. Torrey Club **11:** 134. D 1884.

1886

6. Additions to the Westchester County flora. Bull. Torrey Club **13:** 6, 7. Ja 1886.
7. Botanical notes in the great valley of Virginia and in the southern Alleghanies. Bull. Torrey Club **13:** 69–76. My 1886.
8. Pluralities of embryos in *Quercus alba*. Bull. Torrey Club **13:** 95. *f. 1–3*. Je 1886.

1887

9. Elongation of the inflorescence in *Liquidambar*. Bull. Torrey Club **14:** 95, 96. My 1887.
10. [*Wistaria* at New Dorp, Staten Island.] Bull. Torrey Club **14:** 208, 209. S 1887.

1888

11. [Review of] *Ulota phyllantha* Bridel, La fructification de.—F. Renauld, J. Cardot. Bull. Torrey Club **15:** 203. 2 Jl 1888.
12. *Hypnum* (*Thuidium*) *calyptratum*. Bull. Torrey Club **15:** 220. 2 Au 1888.
13. *Ulota phyllantha* in fruit from Killarney. Jour. Bot. **26:** 282. S 1888.
14. An enumeration of the plants collected by Dr. H. H. Rusby in South America. 1885–1886. —III Pteridophyta. Bull. Torrey Club **15:** 247–253. 3 O 1888.
    Also as a separate, with double pagination, 247–253 and 29–35; included in: Contr. Herb. Columbia Coll. no. 6.
15. [Review of] General index to the first twenty volumes of the Journal (Botany) and the botanical portion of the Proceedings, Nov., 1838, to June, 1886, of the Linnaean [Linnean] Society. Bull. Torrey Club **15:** 268. 3 O 1888.

1889

16. [Review of] The III and IV decades of American Hepaticae [by Lucien Marcus Underwood and Orator Fuller Cook]. Bull. Torrey Club **16:** 79. 8 Mr 1889.
17. Contributions to American bryology.—I. Bull. Torrey Club **16:** 106–112. *pl. 91*. 8 Ap 1889.
    An enumeration of mosses collected by Mr. John B. Leiberg, in Kootenai Co., Idaho.
    Also as a separate: Contr. Herb. Columbia Coll. no. 10.
18. [Review of] Hepaticae, Westindische. F. Stephani. Bull. Torrey Club **16:** 120. 8 Ap 1889.
19. [Review of] Mosses found at Ottawa.—Description[s] of new species of—N. C. Kindberg. Bull. Torrey Club **16:** 141. 8 My 1889.
20. [Review of] Neue Beiträge zur Moosflora von Neu-Guinea.—Von Adelbert [Adalbert] Geheeb. Bull. Torrey Club **16:** 167. 8 Je 1889.
21. *Grimmia torquata* Horns. fertile. Rev. Bryol. **16:** 38, 39. [Je] 1889.
22. [Review of] Kansas fungi. Kellerman and Swingle. Bull. Torrey Club **16:** 196. 6 Jl 1889.
23. *Cladosporium epibryum* Cooke and Massee. Bull. Torrey Club **16:** 225, 226. 1 Au 1889.
24. Peristome of *Grimmia torquata* Hornsch. Rev. Bryol. **16:** 64. [Au] 1889.
25. Germination of lichens on moss protonema. Bull. Torrey Club **16:** 248–250. 19 S 1899.
    Review of "Germination des Lichens sur les protonémas des Mousses," by Gaston Eugéne Marie Bonnier (Rev. Gén. Bot. **1:** 165–169. *pl. 8*).

26. [Review of] Canadian mosses. J. Macoun. [Fourth century.] Bull. Torrey Club **16:** 306, 307. 8 N 1889.
27. [Review of] British moss-flora. R. Braithwaite. Part XII. Bull. Torrey Club **16:** 331, 332. 10 D 1889.

1890

28. [Review of] Sur la présence en Anjou de l'*Equisetum littorale* Kuhlwein, par M. l'abbé Hy. Bull. Torrey Club **17:** 17, 18. 15 Ja 1890.
29. [Review of] Fern flora of Canada. George Lawson. Bull. Torrey Club **17:** 21. 15 Ja 1890.
30. [Review of] Ghiesbreght—Explorador de Mexico—Jose N. Roriosa [Rovirosa]. Bull. Torrey Club **17:** 21, 22. 15 Ja 1890.
31. [Review of] Sur les procédés employés par les Japonais pour obtenis des arbres nains; par M. P. Maury. Bull. Torrey Club **17:** 40. 5 F 1890.
32. [Review of] Les plantes aquatiques alimentaires. A. Paillieux et D. Bois. Bull. Torrey Club **17:** 40, 41. 5 F 1890.
33. Hybrid grimmias. Bull. Torrey Club **17:** 157, 158. 9 Je 1890.
34. [Review of] Laboulbeniaceae.—On some North American species of. Roland Thaxter. Bull. Torrey Club **17:** 165. 9 Je 1890.
35. [Criticism of] New mosses of North America. III–IV. Renauld and Cardot. Bot. Gaz. **15:** 151. Je 1890.
36. [Review of] *Tuomeya fluviatilis* Harvey—Concerning the structure and development of. Wm. A. Setchell. Bull. Torrey Club **17:** 189. 1 Jl 1890.
37. [Review of] Collemaceae and allied groups—On the carpologic structure and development of the. Wm. C. Sturgis. Bull. Torrey Club **17:** 181, 182. 1 Jl 1890.
38. [Review of] Artificial keys to the genera and species of mosses recognized in Lesquereux and James' Manual of the mosses of North America. Chas. R. Barnes. Bull. Torrey Club **17:** 180, 181. 1 Jl 1890.
39. Preliminary list of the mosses of Staten Island. [1–4.] Jl 1890.
    Proc. Nat. Sci. Assoc. Staten Isl., special no. 10.
40. [Review of] Mosses—New Canadian. N. C. Kindberg. Bull. Torrey Club **17:** 222. 12 Au 1890.
41. A handbook of the mosses of northeastern America. Bull. Torrey Club **17:** 260. 9 O 1890.
    Announcement of a proposed work that was never published.
42. [Review of] Hépatiques nouvelles des colonies françaises. E. Bescherelle et Richard Spence [Spruce]. Bull. Torrey Club **17:** 266. 9 O 1890.
43. [Review of] Hepaticae novae americanae tropicae et aliae. Richard Spruce. Bull Torrey Club **17:** 266. 9 O 1890.
44. [Review of] North American Sphagna—Contributions to the knowledge of. C. Warnstorf. Bull. Torrey Club **17:** 296. 9 N 1890.
45. [Review of] Hepaticae britannicae exsiccatae, Carrington and Pearson; Fas. IV. Bull. Torrey Club **17:** 319. 9 D 1890.
    Not signed, but authorship indicated in volume-index.
46. List of the mosses collected [in southwestern Virginia]. Mem. Torrey Club **2:** 52, 53. 23 D 1890.

1891

47. [Review of] British moss flora, II. Part XIII. R. Braithwaite. Bull. Torrey Club **18:** 24, 25. 20 Ja 1891.
48. [Review of] Hepaticae—List of Canadian. W. H. Pearson. Bull. Torrey Club **18:** 28, 29. 20 Ja 1891.
49. Contributions to American bryology.—II. Bull. Torrey Club **18:** 49–56. *pl. 114.* 12 F 1891.
    A supplementary enumeration of the mosses collected by Mr. John B. Leiberg in Idaho, with descriptions of two new species.
    Also as a separate: Contr. Herb. Columbia Coll. no. 18.
50. [Review of] Key to the genera and species of British mosses. Rev. H. G. Jameson. Bull. Torrey Club **18:** 128, 129. 4 Ap 1891.
51. [Review of] Vorläufige Mittheilungen über die von mir im Jahre 1888 in Nord Amerika gesammelten neuen Arten und Varietäten der Laubmoose, von Dr. Julius Röll. Bull. Torrey Club **18:** 165. 1 My 1891.

52. [Review of] Hepaticae americanae, L. M. Underwood and O. F. Cook. [Decades IX–X.] Bull. Torrey Club **18:** 216. 1 Jl 1891.

1892

53. [Review of] An enumeration of all the species of Musci and Hepaticae recorded from Japan. Wm. Mitten. Bull. Torrey Club **19:** 24. 15 Ja 1892.
54. [Review of] Canadian Hepaticae, named by W. H. Pearson, of Manchester, collected and distributed by John Macoun. Bull. Torrey Club **19:** 97. 5 Mr 1892.
55. [Review of] *Fontinalis*.—Tableau méthodique et clef dichotomique du genre. J. Cardot. Bull. Torrey Club **19:** 98, 99. 5 Mr 1892.
56. [Review of] Hepaticae americanae. Prepared by L. M. Underwood and O. F. Cook. [Decades XI–XII.] Bull. Torrey Club **19:** 99. 5 Mr 1892.
57. [Review of] Hepaticae—An arrangement of the genera of. By A. W. Evans. Bull. Torrey Club **19:** 99, 100. 5 Mr 1892.
58. [Review of] Mosses—Some new species from the Pribylof Islands, Behring Sea. Collected by Jas. M. Macoun. N. C. Kindberg. Bull. Torrey Club **19:** 100. 5 Mr 1892.
59. [Review of] Mosses from Behring Sea, collected by Jas. M. Macoun. N. C. Kindberg. Bull. Torrey Club **19:** 100. 5 Mr 1892.
60. [Review of] Mosses of Lancaster County, Pennsylvania—Preliminary list of. J. K. Small. Bull. Torrey Club **19:** 135. 5 Ap 1892.
61. [Review of] *Orthotrichum* de l'Amérique—De quelques formes [d']. Venturi. Bull. Torrey Club **19:** 165. 5 My 1892.
62. [Review of] Outlines of lessons in botany—Jane H. Newell. Bull. Torrey Club **19:** 165, 166. 5 My 1892.
63. [Review of] *Ulota americana* Mitten. F. Venturi. Bull. Torrey Club **19:** 169, 170. 5 My 1892.
64. *Leucobryum minus* Hampe. Bull. Torrey Club **19:** 189–191. 4 Je 1892.
65. [Review of] Étude sur le genre *Eustichia* (Brid.) C. Mueller. Emile Bescherelle. Bull. Torrey Club **19:** 257. 10 Au 1892.
66. [Review of] Plants of the Pribilof Islands, Behring Sea. C. Hart Merriam. Bull. Torrey Club **19:** 260, 261. 10 Au 1892.
67. Nomenclator bryologicus. Bull. Torrey Club **19:** 273. 10 S 1892.
68. [Review of] Catalogue of Canadian plants, Part VI.—Musci. John Macoun. Bull. Torrey Club **19:** 275, 276. 10 S 1892.
69. [Review of] Fontinalacées—Monographie des. J. Cardot. Bull. Torrey Club **19:** 317, 318. 10 O 1892.
70. [Review of] Enumeratio muscorum Caucasi. V. F. Brotherus. Bull. Torrey Club **19:** 318. 10 O 1892.
71. Musci [of West Virginia]. Bull. W. Va. Agric. Exp. Sta. (no. 24) **2:** 484–498. illust. "Je" [N] 1892.
    Also as a separate (under the title "West Virginia mosses"): Contr. Herb. Columbia Coll. no. 32.

1893

72. [Review of] Rabenhorst's Kryptogamen Flora, Part 21. Bull. Torrey Club **20:** 260. 17 Je 1893.
73. The Jaeger moss herbarium. Bull. Torrey Club **20:** 335, 336. 10 Au 1893.
74. Contributions to American bryology, III. Bull. Torrey Club **20:** 393–405. 20 O 1893.
    Notes on the North American species of *Orthotrichum*.
    Also as a separate: Contr. Herb. Columbia Coll. no. 39 (paged 393–404, with lines rearranged throughout so as to bring all matter of original page 405 on page 404).
75. [Review of] Su alcune briofite fossili. U. Brizi. Bull. Torrey Club **20:** 410. 20 O 1893.
76. Notes on two of Palisot de Beauvois species of *Orthotrichum*. Rev. Bryol. **20:** 99. [D] 1893.

1894

77. Contributions to American bryology, IV. Bull. Torrey Club **21:** 1–15. 25 Ja 1894.
    Notes on the North American species of *Orthotrichum*—II.
    Also as a separate: Contr. Herb. Columbia Coll. no. 44.
78. Contributions to American bryology, V. Bull. Torrey Club **21:** 65–76. 20 F 1894.

Notes on the North American species of *Weissa* (*Ulota*).
Also as a separate: Contr. Herb. Columbia Coll. no. 48.

79. How to study the mosses. I. Observer **5:** 82–86. Mr 1894.
80. Bryophyta [collected in southwestern Virginia]. Mem. Torrey Club **4:** 172. 2 Ap; 173–188. 16 Ap; 189–191. 17 Ap 1894.
81. How to study the mosses. II. Observer **5:** 114–120. illust. Ap 1894.
Polytrichum; Pogonatum.
82. Contributions to American bryology—VI. Bull. Torrey Club **21:** 137–160. 25 Ap 1894.
I. Western species of *Orthotrichum* (137–159).—II Supplementary notes on the North American species of *Weissia* (*Ulota*) (159, 160).
Also as a separate: Contr. Herb. Columbia Coll. no. 52.
83. How to study the mosses. III. Observer **5:** 151–157. illust. My 1894.
Catherinea; Georgia.
84. Contributions to American bryology.—VII. Bull. Torrey Club **21:** 189–208. *pl. 197–203.* 25 My 1894.
A revision of the genus *Physcomitrium.* with descriptions of five new species.
Also as a separate: Contr. Herb. Columbia Coll. no. 54.
85. How to study the mosses, IV. Observer **5:** 180–186. illust. Je 1894.
Funaria; Physcomitrium.
86. How to study the mosses, V. Observer **5:** 215–219. illust. Jl 1894.
Ditrichum; Ceratodon.
87. How to study the mosses, VI. Observer **5:** 246–251. illust. Au 1894.
Bryum; Mnium.
88. Contributions to American bryology.—VIII. Bull. Torrey Club **21:** 343–372. *pl. 213–217.* 20 Au 1894.
A revision of the genus *Bruchia*, with descriptions of types, and one new species.
Also as a separate: Contr. Herb. Columbia Coll. no. 60.
89. How to study the mosses. VII. Observer **5:** 306–311. illust. O 1894.
Leucobryum; Fissidens.
90. A revision of the genus *Physcomitrium.* [Abstract]. Proc. Am. Assoc. Adv. Sci. **42:** 261. 1894.

1895

91. Contributions to American bryology.—IX. Bull. Torrey Club **22:** 36–43. *pl. 227.* 15 Ja 1895.
A revision of the genus *Scouleria* with description of one new species.
Also as a separate: Contr. Herb. Columbia Coll. no. 69.
92. How to study the mosses. VIII. Observer **6:** Pract. Micr. 17–21. illust. F 1895.
Dicranum; Bartramia.
93. Contributions to American bryology.—IX [X]. Bull. Torrey Club **22:** 62–68. *pl. 229–231.* 26 F 1895.
1. The systematic position of *Physcomitrella patens* (62–65, *pl. 229, 230*).—2. On a hybrid growing with *Aphanorhegma serrata* Sull. (65–67. *pl. 231*).—3. On a European hybrid of *Physcomitrella patens* (67, 68).
Also as a separate: Contr. Herb. Columbia Coll. no. 72.
94. A revision of the genus *Scouleria.* [Abstract.] Proc. Am. Assoc. Adv. Sci. **43:** 292. Mr 1895.
95. Some notes on the genus *Eucalypta* [*Encalypta*]. [Abstract.] Proc. Am. Assoc. Adv. Sci. **43:** 292. Mr 1895.
96. A hybrid among the mosses. [Abstract.] Proc. Am. Assoc. Adv. Sci. **43:** 292. Mr 1895.
97. Lycopodiaceae [collected in Bolivia by Miguel Bang]. Mem. Torrey Club **4:** 271. 27 Ap 1895.
98. Filices [collected in Bolivia by Miguel Bang]. Mem. Torrey Club **4:** 271–273. 27 Ap 1895.
99. Contribution[s] to American bryology.—XI. Bull. Torrey Club **22:** 447–458. *pl. 248, 249.* 30 N 1895.
1. *Coscinodon Raui* and *Coscinodon Renauldi* (447–449 *pl. 248*).—2. *Dicranella heteromalla* and its varieties (449–452. *pl. 249*).—3. Notes on the genus *Leersia* Hedw. (452–458).
Also as a separate: Contr. Herb. Columbia Coll. no. 81.

1896

100. The luminous moss. [*Schistostega.*] Observer **7:** 15–20. illust. Ja 1896.
101. [Review of] Die Laubmoose. Part 27, Hypnaceae. Bull. Torrey Club **23:** 61, 62. 29 F 1896.
102. The humpbacked elves. [*Buxbaumia* and *Webera.*] Observer **7:** 105–113. illust. Mr 1896.
103. [Review of] Remarques sur la nomenclature bryologique. Bull. Torrey Club **23:** 110–112. 29 Mr 1896.
104. [Cryptogamic botany.] Salutatory. Observer **7:** 161–163. Ap 1896.
105. Notices about specimens. Observer **7:** 163. Ap 1896.
106. Vienna Exchange Office for Cryptograms. Observer **7:** 163. Ap 1896.
107. The trailing Christmas-green. *Lycopodium complanatum.* Observer **7:** 164, 165. *pl.* Ap 1896.
108. How I found *Schizaea pusilla.* Linn. Fern Bull. **4:** 17–19. Ap 1896.
109. Vienna Exchange Office for Cryptograms. Bull. Torrey Club **23:** 152. 30 Ap 1896.
110. [Review of] Musci Americae septentrionali exsiccati. Bull. Torrey Club **23:** 159, 160. 30 Ap 1896.
111. The Brownies. [*Phascum* and *Pleuridium*]. Observer **7:** 246–254. illust. My 1896.
112. Notes on the mosses. Observer **7:** 255–257. My 1896.
113. Criticisms on Renauld and Cardot Musci Americae septentrionalis exsiccati. Bull. Herb. Boiss. **4:** 476–478. Je 1896.
    Also as a separate.
114. The water nymphs. [*Fontinalis* and *Dichelyma.*] Observer **7:** 442–447. illust. Jl 1896.
115. Criticisms of "New or less known species of acrocarpous mosses from North America and Europe" by N. C. Kindberg. Rev. Bryol. **23:** 72, 73. [Au] 1896.
116. The umbrella mosses. [*Splachnum* and *Tetraplodon.*] Observer **7:** 637–645. illust. O 1896.
117. Rediscovery of *Schizaea pusilla* in Newfoundland. Linn. Fern Bull. **4:** 62, 63. O 1896.
118. An enumeration of the plants collected by H. H. Rusby, in Bolivia, 1885–1886.—II. Musci. Bull. Torrey Club **23:** 471–499. 28 D 1896.
    Also as a separate, with double pagination, 471–499, and 9–28, 28a–28i; included in: Contr. Herb. Columbia Coll. no. 6.

1897

119. Emily L. Gregory. Bull. Torrey Club **24:** 221–228. portr. 29 My 1897.
120. The sword moss. [*Bryoxiphium*] Pl. World **1:** 1–5. illust. O 1897.
121. A revision of the North American species of *Ophioglossum.* Bull. Torrey Club **24:** 545–559. *pl. 318, 319.* 30 D 1897.
    Also as a separate: Contr. Dep. Bot. Columbia Univ. no. 137.

1898

122. Four new species of *Ophioglossum.* Fern Bull. **6:** 1, 2. Ja 1898.
123. The adder's tongue ferns. Pl. World **1:** 85–89. *pl. 3.* Mr 1898.
124. List of mosses collected at Arlington, Staten Island, Sept. 27, 1896. Proc. Nat. Sci. Assoc. Staten Isl. **6:** 54. Mr 1898.
125. *Anacamptodon splachnoides* (Frölich) Brid. Fern Bull. **6:** 41, 42. Ap 1898.
126. A hybrid moss. Pl. World **1:** 138. Je 1898.
127. Mosses of northern India. Bull. Torrey Club **25:** 398. 15 Jl 1898.
128. [*Asparagus.*] Pl. World **1:** 176. Au 1898.
129. Edible fungi. Pl. World **2:** 9–11. O 1898.
130. Microscopic preparations of mosses. Fern Bull. **6:** 89, 90. O 1898.

1899

131. A new Tertiary fossil moss. Bull. Torrey Club **26:** 79–81. 8 F 1899.
    Also as a separate.
132. Fossil mosses. Pl. World **2:** 108, 109. Ap 1899.
133. Variation in *Polypodium vulgare.* Fern Bull. **7:** 34, 35. Ap 1899.
134. A bryological memorial meeting at Columbus, Ohio. Fern Bull. **7:** 77, 78. Jl 1899.
135. A new *Grimmia* from Mt. Washington. Rhodora **1:** 148, 149. *pl. 7.* 1 Au 1899.

1900

136. Distribution of the eastern species of *Mnium*. Bryologist **3**: 4–6. Ja 1900.
137. (With Robert Statham Williams.) A new species of *Mnium* from Idaho and Montana. Bryologist **3**: 6, 7. Ja 1900.
138. Mosses in February. Jour. N. Y. Bot. Gard. **1**: 26–29. *f.* 6. F 1900.
139. Mosses in March. Jour. N. Y. Bot. Gard. **1**: 40–43. *f. 9, 10*. Mr 1900.
140. How to know some of the commoner bryums. Bryologist **3**: 16–19. illust. Ap 1900.
141. Mosses in April. Jour. N. Y. Bot. Gard. **1**: 56, 57. *f. 13*. Ap 1900.
142. An ice storm. Jour. N. Y. Bot. Gard. **1**: 72–74. *f. 16*. My 1900.
143. *Fissidens grandifrons* Brid. Bryologist **3**[3]: 4, 5. [**3**: 28, 29.] Jl 1900.
144. [Review of] On the genus *Fissidens*, by Ernest Stanley Salmon. Bryologist **3**[3]: 5, 6 [**3**: 29, 30]. Jl 1900.
145. A note [on *Cinclidotus fontinaloides*]. Bryologist **3**[3]: 6. [**3**: 30.] Jl 1900.
146. *Entosthodon Leibergii*, sp. nov. Bryologist **3**[3]: 10, 11 [**3**: 34, 35]. illust. Jl 1900.
147. Notes. Bryologist **3**: 45. 8 O 1900.
148. Note on *Trichostomum Warnstorfii* Limpr. Rev. Bryol. **27**: 71. [O] 1900.
149. Bryological notes.—I. Bull. Torrey Club **27**: 648, 649. 29 D 1900.

1901

150. The rare mosses of Bashbish Falls. Torreya **1**: 9. 29 Ja 1901.
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180. The relations of plants to birds and insects. Pl. World **7:** 69, 70. Mr 1904.
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The development of the shoot, male flower and seedling of Batis maritima L.[1]

DUNCAN S. JOHNSON

(WITH PLATES 1–3)

INTRODUCTION

The general structure of the vegetative organs, flowers and seeds of *Batis* have been studied more or less carefully by a number of workers and its possible relationship has been discussed by many more. Several quite different hypotheses have been published of the affinities of *Batis* with other Dicotyledons. These have been summarized in some detail, among others by Torrey (1853, p. 3), by Dammer (1893, p. 118), and most recently by Uphof (1930, pp. 355–367). I may here mention a few of the affinities that have been assigned to this plant, merely to show how unsettled the question of its natural relationship still is.

Patrick Browne (1756, p. 356) gave this plant its generic name and the first description that could adequately serve as a basis for guessing at its relationship. Kunth (1816, p. 193) places *Batis* among the Chenopodiaceae. Sprengel (1826, p. 901) thinks *Batis* may belong among the Coniferae. Seubert (1844, p. 753) compared the male spike of *Batis* with that of *Sarcobatus* and that of certain Chenopodiaceae and suggests that *Batis* resembles such Chenopodiaceous genera as *Salicornia.*

A. de Candolle (1873, p. 34) put the Batidaceae between the "Salsolaceae" and the Lennoaceae. Bentham and Hooker (1830, p. 88) rank the Batidaceae between the Phytolaccaceae and the Polygonaceae. Van Tieghem (1884) says that the affinities of the Batidales are quite obscure, but that *Batis* resembles the Chenopodiaceae in its male flower, the Phytoloecaceae in its pluricarpellous pistil and the Gyrostemonaceae in its dioecism. Baillon (1888, p. 254) places the Batidaceae between the Salicaceae and the Podostemonaceae. Dammer (1893, p. 118) after characterizing the genus by certain vegetative, anatomical and floral features, concludes that all evidence then available indicates that *Batis* is quite isolated from other dicotyledons. He places this order between the Amarantaceae and the Phytolaccaceae. Van Tieghem (1903, p. 363) places the Batidaceae in the "alliance" Piperales, between the Salicaceae and the "Liquidambaracees." Engler and Gilg (1924) put the order Batidales between the Juglandales and Fagales with the comment "steht vollig isoliert." Uphof (1930, pp. 355–367) gives an extended summary of the views of all earlier workers on the affinities of *Batis* and a good account

[1] Botanical Contribution No. 123 from the Johns Hopkins University.

of the habit, ecology and organography, both vegetative and reproductive, but he offers no opinion of his own regarding its affinities.

The present study of this fleshy-leafed salt marsh shrub of neotropical strands was made in order to determine what light the development and anatomy of the shoot, flowers and fruit of *Batis* may throw on the precise relationship of this genus. One still more general question in mind was that of the supposed primitiveness of this genus among dicotyledons.

MATERIAL

Male and female inflorescences and mature fruits of *Batis* were collected by the writer near Kingston, Jamaica, in July of 1919, of 1926 and of 1932. These were fixed in chrom-acetic acid fixative or in one of formol, acetic acid and alcohol. Ripe seeds from Jamaica were germinated in Baltimore in November 1926. Other material of this species has been collected for the author by Dr. John K. Small at Miami, Florida, by Dr. Louis J. Pessin in Louisiana and by Prof. J. C. Th. Uphof on the east coast of Florida. The seedlings grew for nearly two years in Baltimore. Transplanted mature plants lived a year and more but never flowered, even though watered with brackish water.[2]

Batis maritima L. is a maritime shrub or half shrub of wide distribution on both Atlantic and Pacific tropical coasts of the three Americas and of the Hawaiian Islands. It is a half-erect half-creeping plant with drooping branchlets (fig. 1). It has opposite, stipulate, half-cylindrical, fleshy leaves and inconspicuous individual flowers in compact spikes (or catkins). The fruits are compound, fleshy and persistently green. In external form the fruits resemble a diminutive potato tuber or the fruit of *Opuntia leptocaulis* (figs. 1, 2). Near Ferry River, west of Kingston, Jamaica and at other points *Batis* forms dense tangles, with its slender sprawling branches covering many square meters of low ground subject to tidal overflow by salt or brackish water. The plants here grow to about half a meter in height and are often overtopped, sometimes shaded out, by the black mangrove *Avicennia nitida* and by the salt marsh fern *Acrostichum aureum*. The rather extensive root system of mature *Batis* plants is made up chiefly of adventive roots arising on the creeping stems. These roots differ widely in size and in complexity of internal structure.

The often upright main stem or trunk of *Batis* may become three or four centimeters in diameter. It branches repeatedly near the ground and the slender, half-creeping branches arising from these main axes range

[2] Material was collected in Jamaica while studying other problems there, aided by a grant from the Bache Fund of the National Academy of Sciences.

three to eight or ten millimeters in diameter. From these half-erect branches are produced the green, 4-angled, erect and then drooping branchlets (or spurs) that bear most of the leaves and flowers (figs. 1, 3). The young stems have small, widely spaced vascular strands (see Solereder 1908, pp. 668, 1032), and Van Tieghem (1903, p. 363). The tracheal elements of these are chiefly spiral in type (figs. 15, 16). Leaf gaps and branch gaps are prominent in cross sections of the stem (figs. 8, 9, 10).

The leaves of *Batis* are opposite, glaucous and quite fleshy. When mature they are almost cylindrical in the upper third, while the middle is semicylindrical (fig. 14) and the basal fifth is decidedly grooved on the upper or adaxial side where it partially clasps about the stem (figs. 10, 11, 13, 19). The tip of the leaf is definitely pointed, sometimes really mucronate (figs. 2, 7, 16). The leaf is sessile and is united to the stem by a relatively small area of attachment at about half a millimeter above its clasping lower extremity (figs. 1, 5, 7, 19). Two leaf traces pass into each leaf (figs. 9, 20) but each immediately breaks up into two on entering the leaf. Just beyond the base the two median, and thus adjacent ones, of the four branches so formed unite to form a large median vascular bundle (figs. 7, 11, 13, 14). Later the marginal branch of each of the two original leaf traces forks once or twice further to give rise to the two or three branches that run upward in each half of the leaf (figs. 12, 13). Connected with the ends of many of the branchlets of the bundles of the leaf, are numerous small, isodimensional groups of short, scalariform tracheids (figs. 14, 16). These groups are most abundant near the tip of the leaf and most of them are nearer the dorsal or abaxial side. The tracheids differ strikingly from the (ordinary) xylem conducting elements of the leaf in having strongly reticulate thickenings instead of the spiral, or more rarely annular, thickenings characteristic of the vessels (figs. 16, 26). These reticulate tracheids are connected to the ends of the smaller vascular branchlets of the leaf. They seem to have no connection with any external opening, or water pore, nor with air spaces among the palisade cells. The function of these tracheids is perhaps, though this has not been demonstrated, the distribution of water from vascular bundles to the water storage tissue of the fleshy leaf (figs. 14, 15, 16).

The stipules: All descriptions of *Batis* found by the writer characterize its leaves as being without stipules. (See Patrick Browne, 1756, p. 356; Carl Linnaeus 1763, p. 1451; Jacquin 1763, p. 261; Swartz 1781, p. 373; John Lindley 1845, p. 386; Torrey 1853, p. 5; Dammer 1893, p. 119) This supposed lack of stipules has of course played a definite part in determining where the Batidales should be placed among the orders of the Dicotyledoneae.

In the present study, where paraffin sections of the buds and flowers were used, it became evident at once that stipules are constantly present on leaves from very young rudiments up to mature leaves, 6 or 8 nodes back from the terminal bud (figs. 9, 10, 12). The reason that they have not been noticed by earlier observers is the fact that they are very small, are soon covered by the leaf bases and that they often wither and drop off shortly after the leaves have fully matured. Then too most descriptions of *Batis* have been made from herbarium specimens, the stipules of which have withered and fallen in the pressing. In living plants the stipules are occasionally present on the fourteenth exposed node below the terminal bud.

The position of these stipules of *Batis* and their relation to the leaf itself correspond precisely with those given by Goebel (1923, p. 1422), i.e., they arise right and left from the leaf base just as leaflets or leaf teeth arise from the upper part of the leaf. This is evident in a view of the edges of the unopened leaves of a bud (figs. 10, 12, 19). Stipules can often be clearly seen also at each side of a leaf scar after the fall of the leaf, five or six internodes below the last attached leaf (fig. 20 below). Finally the position of the stipule and its intimate connection with the base of the leaf can be demonstrated indubitably in both longitudinal and transverse sections of the buds of *Batis* (figs. 9, 10). Stipules are also present on the bracts of both the male and the female spikes as will be described later.

The stipule as seen from the adaxial or abaxial side is a somewhat ovate, blunt-tipped structure with short, broad stalk (fig. 24). In transverse section the broader part of the stipule shows its thickness to be about half its width (figs. 9, 10). Stipules average 22μ in length, 20μ in width and their greatest thickness is about 10μ. The stalk is often thinner as well as somewhat narrower than the body of the stipule, and is also simpler in internal structure (figs. 10, 22). The internal structure of the stipule is little specialized. There is no vascular bundle. The surface cells of the body of the stipule are decidedly elongated radially, have bulging outer ends and contain moderate-sized nuclei but often have relatively large vacuoles (figs. 22, 23).

The possible function of the stipules is not yet determined. The small size of the stipules in proportion to the neighboring leaf rudiments makes it improbable that they can be of great importance in protecting the leaf rudiments within them. It is conceivable that the stipules have a glandular function, though no very definite evidence of this was obtained. The brownish amorphous substance found between the young leaves in cross sections of the bud may be a secretion of the stipules (fig. 23). This substance, which is soluble in hot water like a mucilage but whose source and chemical

composition is still unknown, may perhaps serve as a lubricant that protects the young leaf and flower rudiments.

THE MALE INFLORESCENCE AND FLOWER

All plants of *Batis* studied seemed strictly dioecious. The writer saw no cases, such as are referred to by Dammer (1893, p. 118), of plants bearing both staminate and pistillate flowers. Not even rudimentary flowers of the opposite sex have been found on plants bearing functional male flowers or those bearing functional female ones. Nor have rudimentary carpels (mentioned by Dammer p. 118) been seen in male flowers.

The male flowers of this species arise in solitary, axillary, four-cornered spikes. Each spike is composed of from ten to thirty pairs of decussate bracts. The six to ten pairs of broad, thick, concave bracts in the middle of the spike are fertile, i.e. each subtends a single staminate flower (figs. 4, 26, 35, 43, 47).

The structure of the mature male flower has been described and figured in considerable detail by Torrey (1853, Pl. XI, figs. 1–10). The bract subtending each flower is nearly circular, short-stalked and blunt-pointed (fig. 25). It is not merely concave upward but it has a decidedly thinner margin at the sides and above (figs. 25, 36, 43). The vascular strand that enters the petiole of the bract breaks up at the base of the blade into five main branches that radiate toward the margins of the blade and run nearer its ventral surface (figs. 25, 26). The three middle branches continue on two-thirds the way to the margin before forking again (fig. 25). Each of the two lateral branches soon forks (fig. 25). Then the twenty or more marginal branchlets of these five main bundles finally anastomose to form a complete vascular ring near the margin of the thickened central portion of the bract (fig. 25). From this marginal vascular ring a series of some twenty-five or thirty short branchlets run outward and dorsally each to end in a small group of water tracheids which lies nearer this dorsal or abaxial surface of the bract (figs. 25, 26, 28, 29). There are no vascular strands or water tracheids in the thin margin of the bract (figs. 25, 29). Each bract bears two small stipules at its base (figs. 12, 25, 42). It is evident from the above given description that the bract of the staminate spike is a decidedly more differentiated structure than is indicated by Torrey (1853, fig. 5).

Each staminate flower has four stamens alternating with four whitish, spatulate, slender-stalked, denticulate "appendages" or staminodia, called petals by Torrey, (figs. 26, 27, 31, 46). All eight of these structures in the quite young flower are enclosed in a sac-like perianth which finally forms a complete capsule which is flattened against the axis of the spike

and also against the under side of the next higher bract (figs. 26, 43, 47).

In the development of the male flower the perianth ("calyx" of Torrey 1853, p. 6) is the first structure to appear (figs. 35, 42). The upper, or adaxial, lobe of the perianth is the earliest part of it to appear, and is also the most rapid in growth. It thus soon bends over the top of the flower and then downward to completely cover the young stamens and staminodia (figs. 35, 36, 37). The ring-like perianth soon closes in from all sides and thus later leaves only a narrow, usually transverse, slit-like opening on the side next the subtending bract (figs. 29, 36, 39, 45). The lobes of the perianth sometimes abut when they meet (figs. 36, 38), but often one lobe overlaps the other, as is seen in either longitudinal or transverse section (figs. 39, 45). As the flower matures this slit becomes tightly closed and difficult to discover in either surface view or section. The perianth thus seems to form a practically completed capsule (figs. 26, 44, 47). The upper lobe of the perianth not only grows downward to cover the stamens, but its outer and middle portion grows outward and upward to form the so-called "crest" of the perianth. This crest finally protrudes between the projecting tip of the bract of its own flower and the thick, middle portion of the next bract above (figs. 26, 39, 47 above).

When the flower finally opens the stamens and staminodia push out of the perianth not by enlargement of the preexisting slit, where the lobes closed together during development, but through a *new* rift. This rupture is transverse to the perianth, on its outer side and is located well up toward the "crest" at its tip (fig. 47 below). This rift is clearly located in the upper of the two lobes of the perianth that were seen in the young flower, but it is below the crest of the opened perianth and not above it as Torrey (1853, p. 6) described it. This leaves the crest itself on the upper "lip" of the opened perianth and not on the lower one where Torrey locates it. Torrey evidently refers to the "lips" that are left above and below the rupture of the opened perianth (1853, p. 6). He says "The calyx is a little cup, consisting of two sepals, which are anterior and posterior to the axis and are united below the middle. The cup is compressed and somewhat two-lipped; the lower lip slightly cucullate and cristate transversely just below the margin" (see Torrey, 1853, fig. 4). Dammer (1893, pp. 118–119) says the perianth (Blütenhülle) is cup-like, closed at first then opening by a transverse rupture leaving the posterior lobe usually larger than the anterior (see Dammer, fig. 71 C. D). Neither of these accounts gives the development of the perianth and therefore they could not relate the line of rupture to the original opening in the young perianth as this study does.

A transverse section of the male flower in its lower half shows the perianth as a flattened ring of tissue five to eight cells in thickness with three

small vascular bundles in its thicker, adaxial wall (figs. 44, 46). Still lower down only one bundle was seen, but higher up there are several branches of each of the three primary bundles. Some of the branches from the two lateral bundles run around to the abaxial side of the perianth (figs. 26, 46). In the thickened upper portion of the perianth, on the outer abaxial side are found a few small groups of the water tracheids that are more abundant in the leaf and in the floral bract (figs. 26, 39).

The whorl of four staminodia (the "petals" of Torrey) stands just within the perianth, two at the right and two at the left of the midplane of the flower, thus alternating with the stamens (figs. 43, 44, 46). Each staminodium has a rather long thin stalk and a broad rhombic-ovate, wavy-margined blade (figs. 27, 31). The stalk is but five or six cells thick and ten or twelve cells wide, it contains no vascular bundle and its outer cell walls are not thickened or appreciably cutinized (figs. 32, 34). The blade of the staminodium is six or eight times as wide as the stalk, i.e., forty or more cells wide, but only four or five cells thick (figs. 31, 33). The surface cells of the abaxial face of the blade have greatly thickened and apparently cutinized walls (fig. 33). This wall is often nearly as thick as the cell cavity itself. The function of these walls, in structures which are enclosed in the perianth till they are practically mature, is not easy to guess, unless they serve to support these papery staminodia after expansion. The stamens would seem to be in no need of such structures for their protection, since they are protected till just before their expansion by both the perianth and the close overlapping of the subtending bracts.

No evidence was found that these so-called staminodia ever were functional stamens. The entire lack of vascular bundles, even at the base of the stalk, and likewise the presence of the cutinized wall on the outer cells of the blade would seem to be evidence against their staminal nature rather than for it.

The stamens of *Batis* arise as four rounded knobs in a ring about the center of the male flower. Two of them stand in the median plane of the flower and the other pair on the diameter at right angles to this (figs. 40, 43, 44). When the young stamen has elongated to two or three times its diameter, the upper half swells to form the anther, a vascular strand appears in its filament, and then four archesporial groups of cells appear in the anther (figs. 44, 46). The stamen matures into one of a usual angiosperm type, with 2-celled (4-sporangiate) introrse anthers (figs. 27, 46). Each anther is attached by its middle to the tip of the filament (fig. 27). The wall of the anther is four cells thick and the hypodermal (parietal) layer is the chief mechanical layer of the wall. The thickened strips on the radial walls of these cells are unusual in that they may be diagonal or

even transverse instead of being always radial as in most angiosperms (figs. 48, 50). The tapetal layer is of darkly staining and rather constantly binucleate cells (fig. 48). The diameter of each tapetal nucleus is about half that of the microspore nucleus (fig. 48).

The microspores of *Batis* are minute (16 to 18μ in diameter) spherical and smooth walled, except for four outward distentions of the thin inner wall which apparently serve as the sprouting points of the microspore (figs. 48, 51). The most mature microspores seen in the anther were binucleate, but the two nuclei could not be shown to be separated by a wall (fig. 51). No microspores were found germinating on the stigma but it is assumed that the somewhat smaller nucleus nearer the wall of the spore is the generative nucleus.

It is hoped that studies, already initiated, on the development of the female inflorescence and seed of *Batis* will be completed in a year. The report of that study will include a discussion of the theoretical bearings of its results and likewise of the phylogenetic implications of the facts recorded in the present paper.

GERMINATION

No record has been found of any observations of the germination of the seeds of *Batis* and no very young seedlings were found in any of the several habitats where the plant was collected in Jamaica. The perfectly healthy appearance of the well stored embryos in the seeds led me to attempt germination in Baltimore, in October 1926, of seeds brought from Jamaica in August of that year. Seeds planted in potting soil mixed with an equal part of sand germinated promptly, (fig. 5) and, watered at first with brackish water later fresh water only, grew quite rapidly for the first four months (figs. 5, 5a, 6) and then slowed down till after reaching a height of 25 to 30 centimeters in 1928 they gradually lost their leaves and died down in the spring of 1929.

As the seed, when mature, has no endosperm or perisperm the mechanics of germination is externally relatively simple. The fact that the radicle of the embryo points toward the axis of the spike makes it necessary that in its exit the root of each seedling should not only burst the tough endocarp of its own seed case, but should also push apart the other seed cases of its own ovary and likewise those of its mate on the other side of the spike.

The cotyledons of the young seedling are fleshy from the time they open (fig. 5). The paired secondary leaves which follow the cotyledons in rapid succession are also thick and succulent even before their opening from the bud (fig. 5 at left). The primary root branches early (fig. 5a) but

the primary axis of the stem under greenhouse conditions remains simple until 10 centimeters or more in height. (fig. 6). The oldest plants grown had but few, short and weak lateral branches.

The attempt to grow in the Botanical Garden at Johns Hopkins University mature rooted plants collected on the shore of the Gulf of Mexico in November 1932 succeeded until spring when the plants were moved from the greenhouse to the open. Then the rabbits, which seemed to enjoy the salty shoots of *Batis*, ate the tips off nearly all the plants. When plants from Florida were planted in a sandy soil with wet subsoil in February 1934 and protected from the rabbits the shoots grew in four months to 45 centimeters in height. None of these shoots had flowered, however, up to June 15, 1934. It is clear that the time required for the seedling to mature and flower can be most satisfactorily determined from seedlings growing in their native habitat.

SUMMARY

This study was undertaken to determine the course of development of the shoot, flower and seedling of *Batis* and the evidence these offer concerning the relative primitiveness and probable relationship of this apparently isolated genus. The succulent shoots of this plant bear fleshy, sessile leaves, attached above a median basal lobe. Each vascular branchlet of the leaf usually ends in a small group of water tracheids lying just beneath the four- or five-tiered palisade layer of the leaf. These tracheids have reticulate thickenings instead of the ring-like or spiral ones that characterize the conducting elements of the xylem. Each leaf bears a pair of quite diminutive, early-withering stipules concealed by its clasping base. These stipules are perhaps glandular in function. The withered stipules often adhere to the stem for several nodes below the oldest attached leaf.

The solitary, axillary, staminate spikes consist of from ten to thirty pairs of broad, thin-margined bracts, of which each bears a male flower in its axil, except one or two pairs at the base and a couple of pairs at the tip. Each bract has two small stipules at its base and each is furnished with numerous vascular strands and water tracheids, both confined to the thickened middle portion. Each male flower consists of four stamens, with two-celled anthers and four broad-bladed papery staminodia outside the whorl of stamens. Not even rudiments of carpels were seen. Stamens and staminodia are enclosed by a sac-like, crested perianth that starts as a ring, closes in to a very small slit and then finally opens by a new rift, far above this original opening of the perianth, but below the crest.

Seeds of *Batis* germinate readily in the greenhouse. Seedlings have

fleshy cotyledons and leaves from the start. The root branches early but the erect stem remains unbranched until 12 or 15 centimeters in height. No seedlings or older plants transplanted from Florida or Louisiana have yet developed flowers in the greenhouse.

No essentially primitive structures have been discovered in this study. The perianth itself seems a decidedly specialized one.

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Explanation of plates

Abbreviations: A, apex of stem, leaf or spike; ax. b, axillary bud; B, base; br, bract; cr, crest of perianth; fl, flower; lf, leaf; lg, leaf gap; lt, leaf trace; pe, perianth; pt, petiole (short leaf stalk); S, stem, sd, staminodium; sn, stamen; sp, spike; st, stipule; wt, water tracheid.

Plate 1

Fig. 1. Living branch of a pistillate plant, showing drooping branchlets, leaves, half-grown and matured fruits. ×¾.

Fig. 2. Several mature, living, green, compound fruits, showing persistent stigmas. ×1½.

Fig. 3. Branch of staminate plant (alcoholic) showing size and form of male spike. ×1.

Fig. 4. Several male spikes showing separated bracts and burst perianths near tip of spikes at left and in middle; extended stamen on each side of vertical spike at right and of horizontal spike at left in middle. ×1½.

Fig. 5. Group of seedlings three weeks from sowing at Baltimore, showing cotyledons, epicotyl and first cauline leaves. ×1¾.

Fig. 5A. Seedling of three weeks showing branching of root. ×1.

Fig. 6. Seedlings four months from sowing showing stem, fleshy leaves and scars of earlier, deciduous, cauline leaves. ×1.

Plate 2

Fig. 7. Longitudinal section of a stem apex bearing leaves, axillary buds and a male spike at left. ×10.

Fig. 8. Transverse section of internode of half-year old stem showing arrangement of vascular bundles of the stem including the leaf traces and large leaf gaps. ×10.

Fig. 9. Transverse section through the sixth node below the bud of a 3-month shoot showing leaf bases, stipules, leaf traces, leaf gaps and vascular system of stem after establishment of a complete cambium ring. ×11.

Fig. 10. Transverse section just below a young node showing clasping leaf bases and the hidden stipules. ×11.

Fig. 11. Transverse section of stem apex (at center) with five pairs of leaves showing arrangement of these and of the vascular bundles in each leaf. ×27.

Fig. 12. Transverse section of male spike showing stem, leaves, a young flower and six stipules. ×30.

Fig. 13. Transverse section of young leaf near base showing vascular strands and epidermis differentiated. ×27.

Fig. 14. Hand section across living mature leaf showing shape of leaf in upper half, three main vascular bundles, many branchlet bundles, and groups of water tracheids beneath the palisade layer. ×11.

Fig. 15. Detail of cross section of living leaf showing palisade cells with chloroplasts, vascular bundle endings and air spaces beneath a stoma. ×100.

Fig. 16. Longitudinal section of tip of young leaf showing vascular bundle ending in group of water tracheids. ×127.

Fig. 17. Epidermis of living leaf showing shape of epidermal cells and varied position, size and form of guard cells, and striated outer walls of the subsidiary cells. Apical end of piece upward. ×100.

Fig. 18. Adaxial face of basal end of living, mature leaf, cut off from stem, showing lobe below petiole and axillary bud and two stipules above the cut off petiole. ×7.

Fig. 19. Tip of living branch showing bases of two leaves with their lower lobes (below at right and left of stem) the right stipule of left leaf and left stipule of right leaf between these leaves, and leaf scar and stipules of a torn off leaf across face of stem. ×25.

Fig. 20. Scar of cut off leaf from eighth node below bud showing its stipules and leaf traces and the axillary bud lying against the surface of the *stem*. The radiating lines indicate the directions of cell rows running out from the depression of stem at base of leaf. ×77.

Fig. 21. Axillary bud, leaf scar, leaf traces and stipules of leaf at node 14 below bud and node 6 below lowest (oldest) attached leaf. Stem and upper leaves living,

stipules brown and rather shrivelled. The two lateral leaves of the axillary bud are seen from the end. Large leaf in middle is the first on abaxial side of the bud. ×77.

Fig. 22. Longitudinal (approximately sagittal) section of three-fourths grown stipule showing internal structure. Part of stipule of the opposite leaf at top. ×295.

Fig. 23. Cross section of young stipule near middle showing internal structure. Also, at three corners of the stipule, the slime-like substance that fills interspaces between leaves and stem. ×295.

Fig. 24. Outer face of mature, brownish stipule from leaf 8 below bud on a living stem showing surface formed by ends of radiating cells. ×107.

Fig. 25. Ventral surface of bract subtending male flower (alcoholic) showing form, stalk, one of its stipules, plan of the vascular system with numerous terminal groups of water tracheids. ×25.

Fig. 26. Sagittal section of male flower and its bract showing closed perianth, two stamens and two staminodia, with water tracheids in both. ×25.

Fig. 27. A ripe stamen with adjoining staminodium, showing insertion of anther and form of staminodium. ×11.

Plate 3

Fig. 28. Tangential section, near margin, of bract of male spike showing vascular bundle endings and groups of water tracheids. ×150.

Fig. 29. Tangential section of a bract and perianth of a male flower showing water tracheids of bract, the nearly closed transverse slit of the young perianth and, near center, part of a second bract. ×25.

Fig. 30. Detail of margin of slit in a nearly closed perianth. ×150.

Fig. 31. Surface view of right half of blade of a staminodium showing wavy margin and cell arrangement. ×55.

Fig. 32. Longitudinal section of base of stalk of a staminodium showing lack of vascular bundles and of cutinized epidermis here. ×150.

Fig. 33. Part of longitudinal section of blade of staminodium showing very thick cuticle on outer side. ×150.

Fig. 34. Transverse section of stalk of staminodium showing simple structure and complete lack of vascular tissue. ×150.

Fig. 35. Longitudinal section of tip of male inflorescence showing three young flowers below with their subtending bracts and two very young ones just below apex. ×50.

Fig. 36. Sagittal section of male flower and bracts showing perianth still open and very young stamens and staminodia. ×50.

Fig. 37. Sagittal section of flower shown in last figure, but two sections beyond, showing nothing of slit in perianth. ×50.

Fig. 38. Sagittal section of somewhat older male flower showing perianth crested but slit still open. ×25.

Fig. 39. Sagittal section of older male flower showing crest well developed and upper lobe of perianth widely overlapping lower. ×25.

Fig. 40. Similar section of practically mature flower showing crest and long bent-over blade of staminodium. ×25.

Fig. 41. Longitudinal section of two anthers of young flower. ×250.

Fig. 42. Transverse section of young male spike showing stem at left, leaf sub-

tending whole spike at right and four flowers with their perianths and subtending bracts. ×20.

Fig. 43. Nearly transverse section of older spike showing in each of two upper flowers, positions of the four stamens and four staminodia. ×25.

Fig. 44. Cross section of half-grown male flower showing structure of perianth, staminodia and anthers. ×150.

Fig. 45. Somewhat obliquely transverse section of a staminodium and of overlapping lips of perianth. ×150.

Fig. 46. Nearly transverse section of single mature male flower showing distribution of vascular bundles in perianth, the staminodia and nearly mature anthers. ×27.

Fig. 47. Longitudinal section (diagonal) of mature (but unusually short) male spike showing sagittal sections of two unopened flowers and (below) two flowers in which stamens have burst through perianth, leaving "crest" of latter above the rupture. ×7.

Fig. 48. Part of longitudinal section of wall of anther showing also spore mother cells and binucleate tapetal cells. ×250.

Fig. 49. Single uninucleate microspore. ×290.

Fig. 50. Part of cross section of wall of mature anther showing mechanical layer and nearly ripe binucleate microspores. ×250.

Fig. 51. A ripe binucleate microspore showing thickened wall and four germ pores. ×800.

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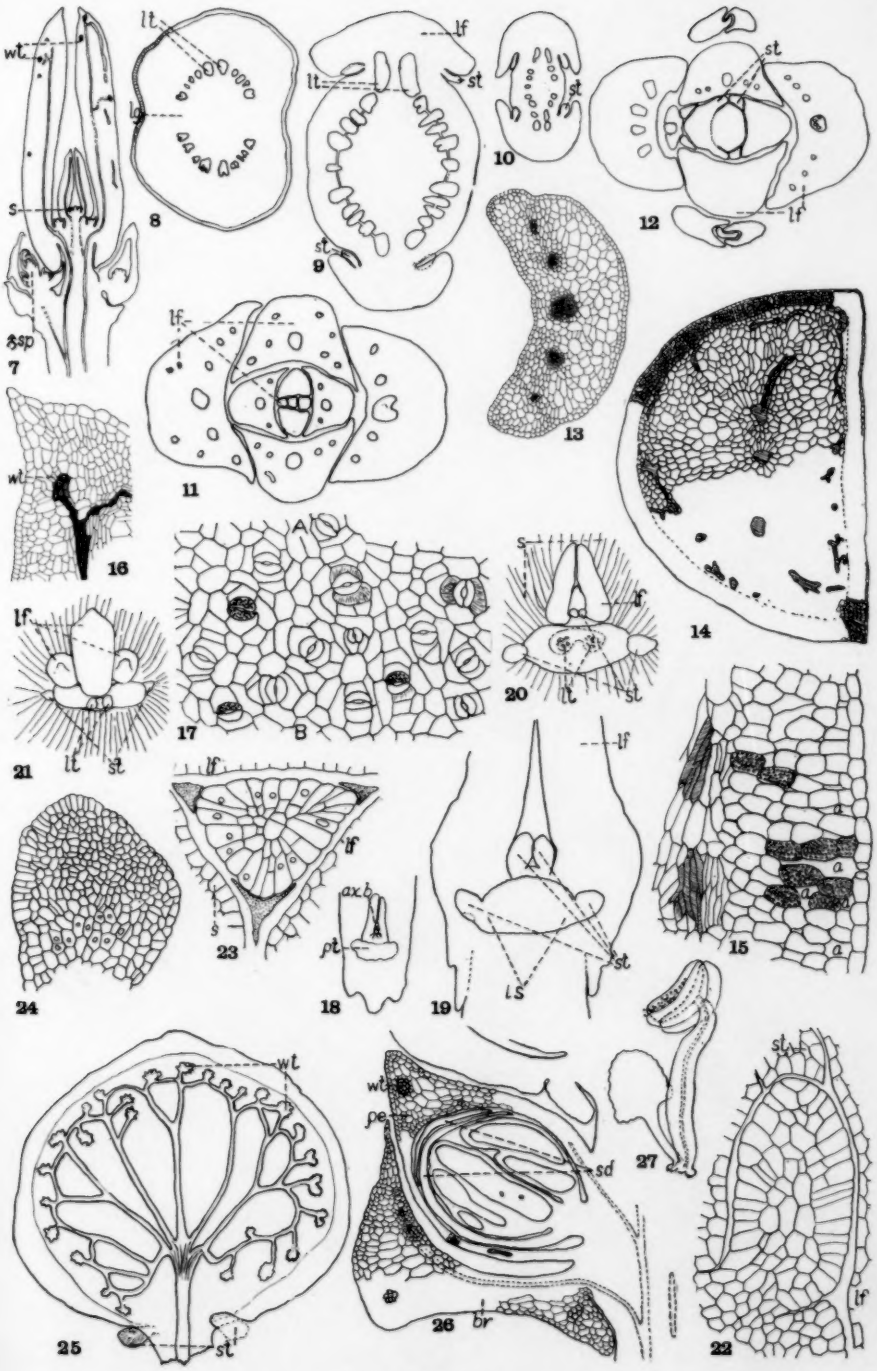
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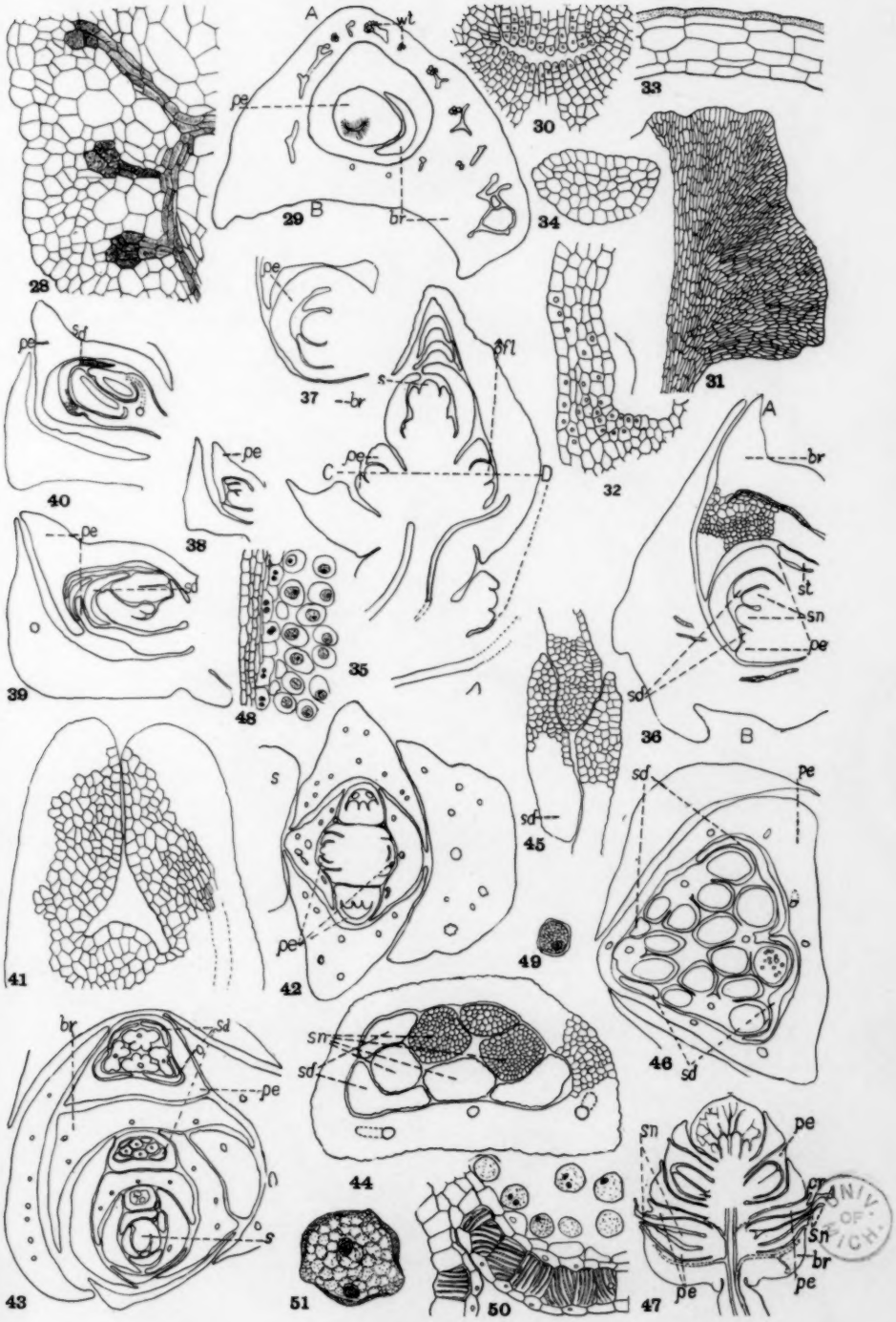
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UNIV. OF MICH.

Riccia fluitans L.—a composite species

ANNETTA M. CARTER

(WITH PLATES 4 AND 5)

A survey of the literature on *Riccia fluitans* L., commonly thought of as an aquatic liverwort, shows that the species has been an object of controversy for some time. There is still some doubt in the minds of investigators as to the exact status of *Riccia fluitans* L. Some believe it to be a composite consisting of the aquatic forms of several terrestrial species of Riccia, while others still believe in treating it in the conventional way, as a distinct species which has both aquatic and terrestrial forms.

In confirmation of the conception of *Riccia fluitans* L. as a composite species, there is Von Gaisberg's (1921) work in Goebel's laboratory at Munich. He carried on cultural experiments with aquatic material from two different localities, from the university greenhouse at Munich, and from the vicinity of Starnberg in Bavaria, and with both he obtained similar results. That is, material from each of these localities, when grown on soil, developed into a sterile "broad form." The interesting point here is that Familler had classified the material from near Starnberg, presumably on its morphological characters, as *Riccia Huebeneriana* Lindenberg. Cross sections of the broad material showed that the outer portion of each flank of a thallus contained a single large air chamber, but that elsewhere the chambers appeared to be in two layers and sometimes, in the median portion, in three layers. According to Evans (1922), these characters might be sufficient to distinguish the broad material from *Riccia Huebeneriana* Lindenberg (as it is usually described) but they are not sufficient to separate it from the "forma *canaliculata*" of *R. fluitans* L. Donaghy (1916), after a series of observations on *Riccia fluitans* as it occurs in Indiana, came to the conclusion that the sterile terrestrial plants derived from aquatic plants were distinct from the so-called terrestrial form which is fertile. He also noted a slight widening in the apices of the aquatic thalli after they had come into contact with the soil. Familler (1920) is firm in the opinion that *Riccia fluitans* L. "consists of two or three aquatic forms of various Ricciae." There is no cultural proof, however, that his characters are not variable.

During the past three years, observations on California forms of *Riccia fluitans*, both in the field and under cultural conditions, have been made. The species was first reported (Evans, 1923) as growing in California by Mrs. E. C. Sutliffe of the California Academy of Sciences who collected it in Lily Lake, Marin County, in September 1921. The next known collection of *Riccia fluitans* in California was made by Herbert L. Mason in

October 1928 in the sloughs of the San Joaquin River, San Joaquin County. This extension in the distribution of the species has not previously been published.

The ecological conditions in the above two California localities where *Riccia fluitans* has been collected differ considerably. Lily Lake is a small pond shaded by redwoods, California bay laurels, and oaks. It is near the coast in the redwood fog belt; so the air temperature range is probably comparatively small. A November temperature of 44.2°F. was obtained. The aquatic thalli grow partially submerged among fallen tree trunks near the edge of the pond. They vary in breadth from 1 to 1.5 mm. The sloughs

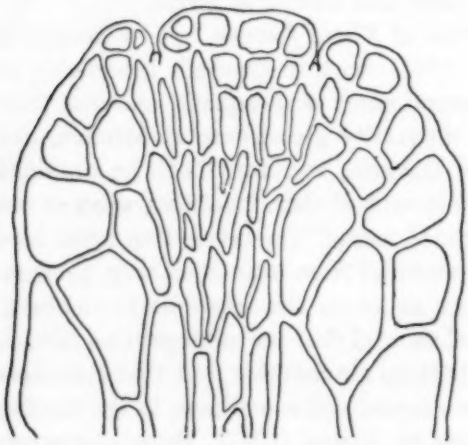

Fig. 1. Tip of a branch (with two growing points) from a broad thallus growing in small pot in the window box. Surface view showing the air chambers in outline. ×25

Fig. 2. Tip of a branch (with one growing point) from a narrow thallus growing in small pot in the window box. Surface view showing the air chambers in outline. ×25

near Holt, on the other hand, present an entirely different aspect. Here, the water is partially shaded by willows or by tules which grow out into it in the shallower areas that are not submerged throughout the year. For this locality a temperature range in the water of 39.6°F. was obtained, that is, 42.8°F. in December and 82.4°F. in July, and doubtless the temperature goes considerably above and below these two points. The aquatic plants float just under the surface of the water, either among the tules or in more open, deeper water in the shade of the willows, while a few terrestrial plants are found growing on floating logs or on the steep, moist banks above the surface of the water. All of the aquatic thalli are narrower than those from Lily Lake, few being more than 0.5 millimeter to 0.75 millimeter broad. This difference in breadth between the *Riccia fluitans* L. from

Lily Lake and that from the Holt sloughs immediately raises the question as to whether the thalli of the plants from these two localities show constant morphological characters that are dissimilar.

Cultures, terrestrial and aquatic, of material from both of these California localities were grown in the laboratory and in the open court of the Life Sciences Building of the University of California. The Lily Lake material remained consistently of the broad type, but the aquatic Holt material, when planted on soil, developed into two distinct types of thalli, a broad type and a narrow type. Cross sections of the broad thalli from both localities show each flank to contain from one to three large air chambers in one story, while the central area contains small or medium-sized chambers

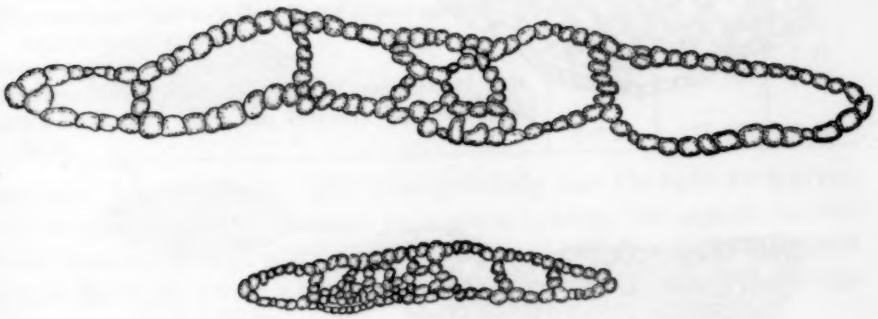

Fig. 3. Broad thallus from pot in the window box. Cross section, ×50.
Fig. 4. Broad thallus from Pot C in court. Cross section, ×50.

in two stories. The narrow thalli which developed from the Holt aquatic material, on the other hand, have a single small or medium-sized air chamber in each flank and small or medium-sized chambers, occasionally in two, but usually in three to four stories in the rest of the thallus. Surface views of the air chambers in the two types of thalli show that those in the broad thalli are polygonal while those in the narrow thalli are long and narrow both in the flanks and in the central region. In addition to the differences, between these two forms, in the type and arrangement of the air chambers, are the differences in growth form when on soil. The broad type of thallus is thin, has short, broad-angled dichotomies, and tends, when not crowded, to grow in "fan-shaped rosettes." The narrow thalli are slender and comparatively thick, have long, acute-angled dichotomies, and tend to spread out over the substratum rather than to form a definite rosette. Another point is that the narrow type of thallus is fertile (spores measure 75–94 microns in maximum diameter in plants grown in the laboratory, while those collected in the field, aquatic, were 84–108 microns

in maximum diameter), and the broad form, so far as the experiments carried through determine, is sterile.

Since cross sections of the two types of thalli showed such differences in the size and arrangement of the air chambers, it seemed as though each type should have a definite width-thickness ratio. A large number of sections were made of both wide and narrow thalli grown under various conditions. (The "submerged" thalli were those which had been returned to an aquatic habitat after having grown on soil for some time. When treated in this way, they became narrower, but their air chamber characteristics

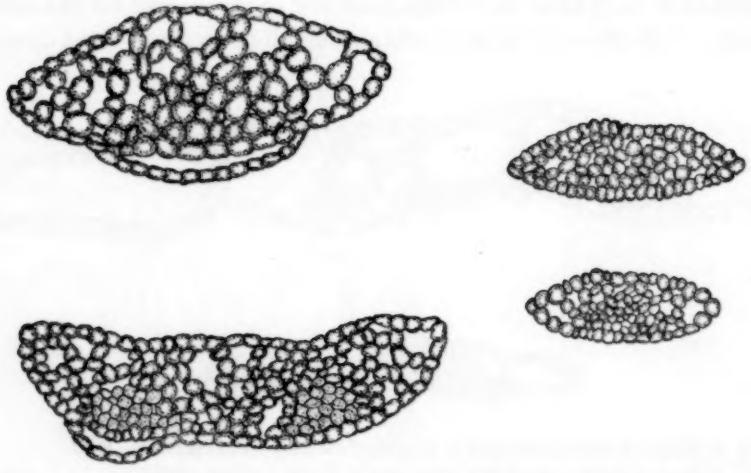

Fig. 5. Narrow thallus from small pot in window box. Cross section, ×50.

Fig. 6. Narrow thallus from small pot in window box. Cut near the apex behind two growing points. Cross section, ×50.

Fig. 7. "Submerged" narrow terrestrial thallus. Cross section, ×50. (Note that it differs from the other narrow thalli only in that it is more compact.)

Fig. 8. Narrow thallus from Pot C in court. Cross section, ×50.

remained constant.) At first, it seemed as if this width-thickness ratio could be used as a definite means of separating the two forms (tables 1, and 2) but further study showed that there was overlapping in a few instances.

In order to show that the broad and narrow terrestrial thalli developed from two distinct aquatic types of thalli, material was selected, on the basis of its air chamber characteristics, from a mixed aquatic culture collected at Holt. Sections were made of part of each thallus and the remainder of each thallus was planted on soil and placed in the window box. Those thalli that had an air chamber arrangement characteristic of the narrow type of thallus grew into narrow thalli on the soil, and those that had the wide type

of air chambers grew into wide thalli. After an interval of seven weeks sections were again made of portions of each thallus and the width-thickness ratio before and after being planted on the soil was compared (table 3.) As in the other width-thickness ratio comparisons there is slight overlap-

TABLE 1

Average of cross section comparisons

TYPE OF THALLUS	WIDTH	THICKNESS	RATIO
Narrow terrestrial thalli from Pots B and C and small pot in window box.	681.26	264.57	2.60
"Submerged" narrow terrestrial thalli.	449.00	160.00	2.76
Narrow terrestrial thalli collected at Holt, 7/29, 9/27, 1931.	677.60	191.90	3.53
Fruiting aquatic thalli collected at Holt, June 15, 1930. Narrow type.	444.12	199.37	2.28
Wide terrestrial thalli from Pots C and D and small pot in window box.	1406.16	199.08	7.07
"Submerged" wide terrestrial thalli.	658.35	120.21	5.48
Mixed aquatic thalli from Holt, July 29, and Sept. 27, 1931.	709.03	173.55	4.35
Aquatic thalli from Lily Lake, February 27, 1932. Broad type.	897.28	175.35	5.18

ping here, but the results show quite definitely that the ratio for a given type of thallus is fairly constant for a given habitat. The *aquatic* narrow thalli have an average width-thickness ratio of 1.99:1 and the *terrestrial* narrow thalli, of 4.4:1; while the aquatic broad thalli have an average

TABLE 2

Maximum—minimum measurements from cross section comparisons

TYPE OF THALLUS	WIDTH	THICKNESS	RATIO
Narrow terrestrial thalli from Pots B and C and small pot in window box.	800–396	352–110	3.77–2.11
"Submerged" narrow terrestrial thalli.	528–330	176–154	3.38–2.01
Narrow terrestrial thalli collected at Holt, September 27, 1931.	759–561	220–154	3.94–3.11
Fruiting aquatic thalli collected at Holt, June 15, 1930.	539–363	330–154	2.78–1.63
Wide terrestrial thalli from Pots C and D and small pot in window box.	1980–682	275–110	8.18–5.60
"Submerged" wide terrestrial thalli.	1045–462	154– 88	8.63–3.83
Mixed aquatic thalli from Holt, July 29, and Sept. 27, 1931.	1078–208	253–121	6.64–1.95
Aquatic thalli from Lily Lake, February 27, 1932.	1100–704	231–121	7.27–3.85

width thickness ratio of 2.91:1 and the terrestrial broad thalli, of 6.8:1. If both the width-thickness ratio and the air chamber characteristics are considered, there should be no difficulty in distinguishing the two types of thalli.

The fact that environmental conditions play an important part in determining the appearance and growth form of *Riccia fluitans* was demon-

TABLE 3

Comparison of broad and narrow thalli before and after planting on soil

	NARROW THALLI							
	AQUATIC				TERRESTRIAL			
	Thick.	*Width*	*Ratio*	*Aver.*	*Thick.*	*Width.*	*Ratio*	*Aver.*
	165	209	1.26		198	979	4.94	
I	209	330	1.57	1.607	209	825	3.94	4.38
	165	275	1.66		121	517	4.27	
	198	385						
II	154	187	1.21	(died)	—	—	—	
	176	286	1.62		220	847	3.85	
III	121	297	2.45	2.02	176	979	5.56	
	143	286	2.00		220	935	4.25	4.44
					253	1100	4.30	
					935	220		
IV	187	473	2.52	2.26				
	176	352	2.00					
	BROAD THALLI							
	165	594	3.6		220	1265	5.75	
	143	440	3.07		220	1320	6.00	
I	198	528	2.66	3.158	209	1254	6.00	6.08
	176	528	3.00		187	1232	6.58	
	143	495	3.46					
II	220	550	2.5	2.5	220	1595	7.25	
					220	2563	11.65	
					231	1496	6.47	7.37
					220	1155	5.25	
					176	1210	6.25	
	165	550	3.33		187	1100	5.88	
	176	506	2.87		220	1683	7.65	
	176	495	2.81		187	1243	6.64	
	165	429	2.60		176	1628	9.25	6.96
III	165	495	3.00	3.07	187	1375	7.35	
	143	550	3.84		220	1100	5.00	
	176	429	2.43					
	198	605	3.05					
	154	572	3.71					

The measurements are in microns.
The ratio is on the basis of the thickness of the thallus being 1.

strated in a series of observations made on the terrestrial cultures growing in the court. (These terrestrial cultures were in pots twelve inches deep

and fourteen inches in diameter. The pots were filled with soil to within five or six inches of the top and were partially submerged in the pool. Due to the depth of the cultures in the pots, the thalli on the south side were shaded during a large part of the day.) During the summer months, the gross aspect of the mass of thalli on the sunny side of the pots is decidedly purple, except in the central area where the conditions, although sunny, are very moist. Closer observation, however, shows that it is the broad thalli, rather than the narrow ones, which develop the greatest amount of anthocyanin pigment. Formation of this pigment takes place rapidly. Two days after a thallus was transplanted from the shady side of the pot to the sunny side it was beginning to show pigment at the base of the thallus, and after five days it was a deep purple except at the very apex. In addition to the formation of the pigment in the thalli on the sunny side of the pot, there was a noticeable slowing up of the growth rate in these same thalli. As winter approached, the purple coloring began to disappear from the plants, and by the last week in November there was not the slightest evidence of anthocyanin pigment in any of the thalli. In the first week of the following March, after several bright, sunny days, the broad thalli were beginning to show the return of the pigment. Cross sections of the wide, purple thalli showed that the pigment was confined, for the most part, to the single, outer layer of cells. In all cases, it was much more dense in the cells of the dorsal surface and diminished gradually in the cells on either flank of the ventral surface. In a few cases, the pigment was found in the unistratose lamellae between the air chambers. The pigment seems to form first in the older parts of the thallus branches, and there is none at all noticeable right at the growing point. Although these observations on the formation of anthocyanin pigments in *Riccia fluitans* touch only upon the surface of the question, it seems to me that they show clearly that the purple coloring in this plant is due entirely to seasonal, environmental changes, and that therefore the presence of the pigment may not be safely used as a character for the classification of the species nor for the classification of any form of the species.

The question of nomenclature in the broad and narrow forms is a difficult one. The *Riccia fluitans* described by Linnaeus cannot be definitely determined without having access to the type material in order to study the arrangement of the air chambers, and there is no record of a type specimen of *Riccia fluitans* in the Linnean herbarium. Since the broad type of thallus is more abundant than the narrow type in the Holt material and since it seems to be the exclusive type in the Lily Lake material, one is inclined towards the belief that it (the more abundant aquatic form, at least in the California material) may represent the type. If this should prove to

be the case, the name *Riccia canaliculata* (Hoffmann) would be free for use on the narrow terrestrial material which corresponds very closely with the description of the above species given by Familler (1920). The broad material, on the other hand, corresponds closely with Familler's "*Riccia Huebenerana*" Lindenberg, except that the California material is consistently sterile. The fact, however, that the California material is sterile agrees with Von Gaisberg's (1921) observations on the "broad form" from Starnberg which Familler had identified as *Riccia Huebeneriana*. Both broad and narrow types grow well, either on land or in the water; so the distinction of one being primarily terrestrial does not hold with our California material. The fact that I have found so much variation in my broad material corresponds with Familler's observations on *Riccia Huebeneriana* and *R. pseudo-Frostii* Schiffner where he found that one could be transformed into the other quite readily. Evans (1923), however, states that in North America *Riccia pseudo-Frostii* Schiffner is replaced by *Riccia Sullivantii* Austin. Therefore the question of whether *Riccia Sullivantii* could be confused with the California broad form might be raised. Dr. Marshall A. Howe kindly provided some living material of *R. Sullivantii* from the New York Botanical Garden and it has been kept growing on soil in the window box. Comparisons of this material with both of the California forms, however, show it to be quite distinct—the central tissue is much better developed; the whole aspect of the cross sections, although the air chambers are in one to three stories, is different; and the median sulcus is much better developed than in any of the California material of these investigations.

Although there is still room for more work on *Riccia fluitans* and the closely related species, it seems to me that in this study of its morphology and behavior several of the important questions that have been raised concerning it are advanced towards settlement. The more important points brought out in this study of *Riccia fluitans* L. as it occurs in California are as follows:—

1. The aquatic material, as it occurs in the sloughs at Holt, seems uniform when observed macroscopically, but when planted on soil two types of thalli develop,—broad and narrow.

2. The broad thalli on soil cultures are characterized, externally, by being thin, having short, broad-angled dichotomies, and growing in "fan-shaped" rosettes. The air chambers tend to be polygonal, and a cross section of the thallus shows that the flanks are one-storied and that each flank contains from one to three large chambers, while the central area contains small, or medium-sized chambers in two, or occasionally, in three stories.

3. This broad material, in so far as can be determined by vegetative characters, seems to correspond closely to Familler's *Riccia Huebeneriana* Lindenberg.

4. The narrow thalli on soil cultures are slender and comparatively thick, have long, acute-angled dichotomies, and tend to spread out over the substratum rather than to form a definite rosette. A surface view of the thalli shows that the air chambers are long and narrow, while a cross section shows that in each flank there is one small or medium-sized chamber and in the rest of the thallus there are small or medium-sized chambers, occasionally in two, but usually in three or four stories.

5. This narrow type of thallus seems to correspond closely with Familler's "*Riccia canaliculata* (Hoffmann) Lindenberg."

6. The characteristic air chamber arrangement in each of these two types of thalli is constant whether the plants are growing in water or on land.

7. The width-thickness ratio, when used with the air chamber characteristics and the habitat, is a fairly reliable diagnostic character.

8. The narrow thalli are much less variable than are the broad thalli.

9. The narrow thalli are fertile, both in aquatic and terrestrial habitats, while the broad thalli are consistently sterile.

10. The presence of anthocyanin pigment in a thallus is not a sufficiently stable character to be used in the classification of the plant.

At this time, I wish to express my appreciation to Professor W. A. Setchell, under whose guidance this work has been carried on, for his kindly suggestions and criticism.

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Explanation of plates

Plate 4

Reproductions all life size

Fig. 1. Broad terrestrial thalli grown in small pot in window box.

Fig. 2. Broad terrestrial thalli grown in small pot in window box and then transferred to water for one month.

Fig. 3. Narrow terrestrial thalli grown in small pot in window box.

Fig. 4. Narrow terrestrial thalli grown in small pot in window box and then transferred to water for one month. (Same type as is shown in cross section, Plate I, Fig. 9.)

Fig. 5. Aquatic thalli collected at Holt, September 27, 1931. (All of these are of the broad type.)

Plate 5

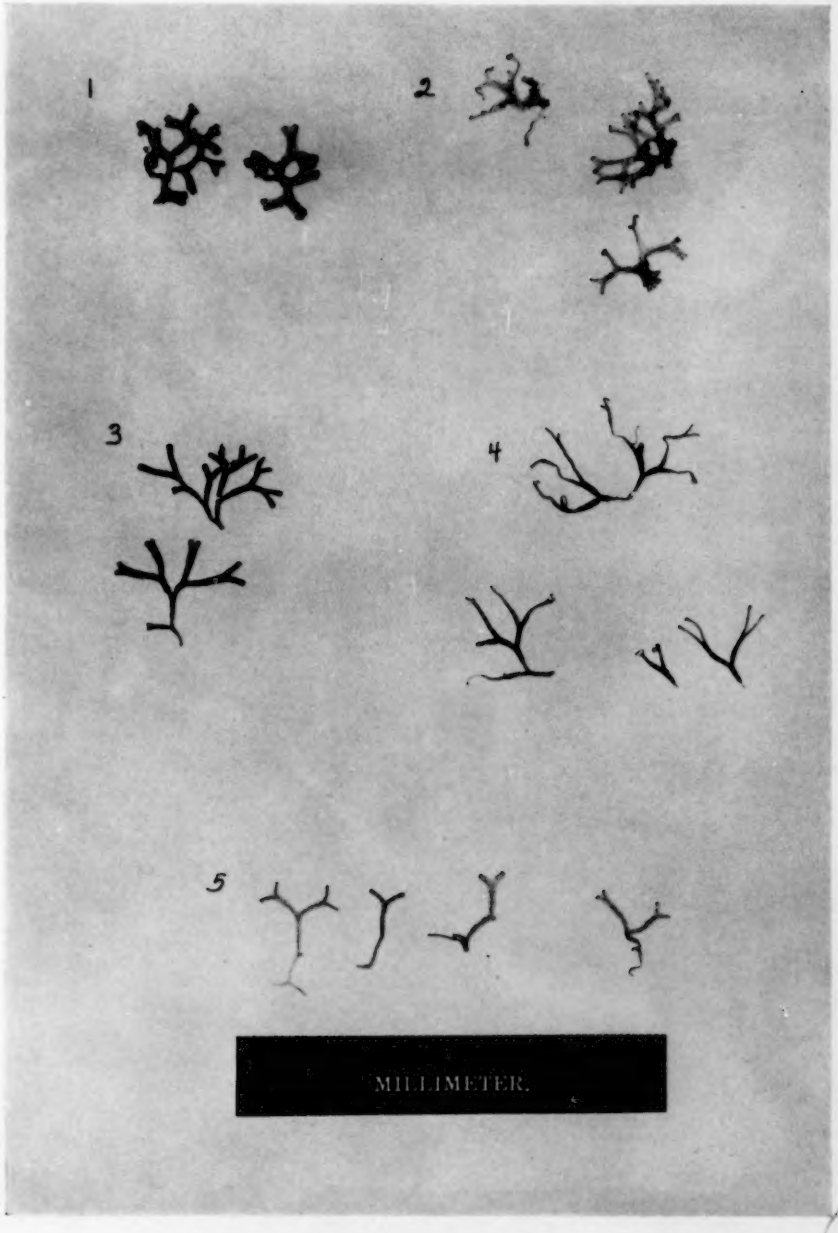
In this plate, the thalli are reduced to 0.55 of their natural size.

Fig. 1. Culture of *Riccia fluitans* collected at Holt, July 29, 1931 and grown in beaker of water in window box until September 22, 1931. It was then planted on agar where it grew until November 10th when the photograph was taken. Note that the thalli are narrower toward the base and wider towards the apices. This widening occurred after they had been planted on the agar.

Fig. 2. Culture of wide thalli from Pot B which grew on agar from September 22 to November 10, 1931.

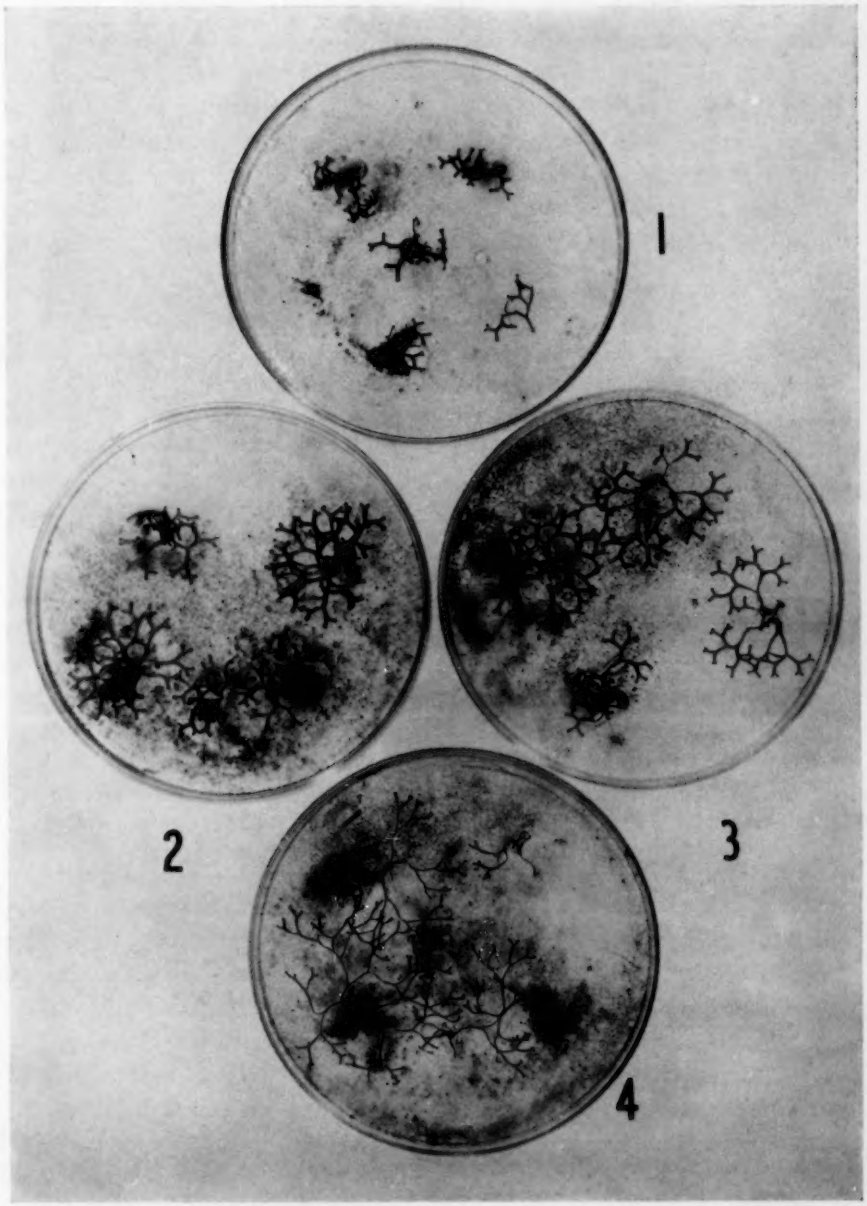
Fig. 3. Culture of broad thalli from Pot C. They were transferred from soil to water where they grew for twenty days. Then they were removed from the water and grown on agar for seven weeks. Note that the thalli are wide at the base, then narrow, and wide again at the apical ends.

Fig. 4. Fruiting thalli from Pot C. These were planted on agar on September 23 where they grew until November 10, 1931 when they were photographed. Note the difference in growth form of these narrow thalli from that of the wide thalli in Figs. 2 and 3.



CARTER: RICCIA FLUITANS

UNIV. OF MICH.



CARTER: RICCIA FLUITANS

A new species of Ephedra from Western Texas

E. L. Reed

In collecting plants along the escarpment and the adjacent broken lands to the east of Palo Duro Canyon, Texas, the writer collected several specimens of an *Ephedra*, vegetative structures only, which, by the available keys, were tentatively identified as *Ephedra antisyphilitica* Meyer, although differences in its habit from that species were noted. In the spring of 1932 the plants "blossomed" freely and an abundant crop of fruit was produced, the first that the writer had seen. From a careful study of the plant, its habit, its fruit, etc. it seems feasible to publish a diagnosis of it as a type of hitherto undescribed species.

Ephedra texana sp. nov. Plant a rigid, low, erect shrub, 1 to 2½ m. tall, branchlets bright green, numerous, more or less erect; scales of the twigs 2 to 6 at each node, forming a sheath 1 to 2½ mm. long, the tips obtuse, 1 to 2 mm. long or subulate, 3 to 9 mm. long; aments on short, scaly stalks; the staminate aments 5 mm. long or less; the stamen column 2 to 5 mm. long; anthers 5, 3 sessile and 2 on short filaments; bracts of the ovulate aments 5 to 6 mm. long or less; perianth lobes only slightly united; fruit an oval, red, fleshy, edible berry about 7 mm. or less in diameter; seeds ovoid, slightly triangular, exserted.

Planta: frutex humilis rigidus erectus 1–2½ m. altus; ramis viridibus numerosis plus minusve erectis; scalis ramulorum 2–6 ad quemque nodum, vagina facta 1–2½ mm. longa, apicibus obtusis 1–2 mm. longis vel sublatis 3–9 mm. longis; amentis in pedunculis brevibus squamosis, amentis masculis 5 mm. minusve longis; columna staminum 2–3 mm. longa; antheris quinque, 3 sessilibus, 2 in filamentis brevibus; bracties amentorum ovulatorum 5–6 mm. minusve longis; lobis perianthi vix coniunctis; bacca ovata, rubescente, carnosa, esculenta cir. 7 mm. crassa; seminibus ovatis, vix triangularibus exertis.

Along the escarpment and the broken country to the east from Palo Duro Canyon southward. Specimens have been collected at Quitaque, Crosbyton, Spur, Lubbock, and Post, Texas. Type locality: Buffalo Springs, Lubbock, Texas. Type specimen is in the National Herbarium, Smithsonian, Washington, D. C. This plant seems to be intermediate between *E. antisyphilitica* and *E. pedunculata*. It differs from them in the following characters: from *E. antisyphilitica* in that (a) its branches are never weak, reclining, or prostrate, (b) its perianth lobes are less united, (c) the tips of the scales are often extended into subulate awns 3 mm. to 9 mm. long, (d) two of the anthers are on short stalks and (e) the fruit is much more fleshy; and from *E. pedunculata* in that its branches are rigid and never climbing over surrounding shrubs, and (b) its aments have scaly instead of naked stalks.

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Effects of ultra-violet radiation and temperature on Fusarium

I. Lethal Action

ELIZABETH C. SMITH
(WITH TWO FIGURES)

INTRODUCTION

A study of the literature reveals a rather meager accumulation of statistical data on the effects of radiation on the fungi. This is rather surprising in view of the fact that the fungi lend themselves readily to mass methods. The literature dealing with the general and qualitative effects of radiation on fungi is, however, extensive. An attempt was made in this investigation to collect statistical data by the use of methods which were as quantitative as seemed feasible for the use of large numbers of individuals. *Fusarium eumartii* Carp. was chosen because pigment is absent in both mycelium and spores and because the size of its spores make possible rapid single spore isolations. Three aspects of radiation and temperature were considered, viz., effects of radiation on spores, effects of temperature on spores, and the relative sensitivity of spores and mycelium.

Lethal effects constitute a phase of the problem which has been given much attention and it is one of considerable interest. Writers have drawn a sharp distinction between sigmoid and logarithmic lethal curves and have given different interpretations to these two types of curves. In this paper data will be presented to show that there is a relation between the two types of curves and that possibly one interpretation will fit both types. Very little study has been previously made of either the effects of sudden changes in temperature on fungus spores or of the relative sensitivity of spores and mycelium.

EFFECTS OF RADIATION ON SPORE GERMINATION

Methods

A suspension of spores was made in sterile distilled water. The spore load (the number of spores in 1 cc. of water) was determined with a Levy counting chamber. Enough of the suspension was added to sterile distilled water to give a spore load of not more than 300. This suspension was kept at 0°C. for 12 hours. It was then plated out on potato-dextrose agar, 1 cc. of the suspension to each sterile Petri dish. The agar was prepared as follows: 200 grams of fresh potato slices were placed in 500 cc. of distilled water. The mixture was brought to a boil and then autoclaved at 15 pounds pressure for 20 minutes. A mixture of 10 grams of agar in 500 cc. of distilled water was treated in the same way. The two mixtures were then com-

bined and 30 grams of dextrose were added. The solution was diluted with distilled water to 1 liter and then filtered through cotton. Preliminary experiments with *Fusarium* cultures on potato-dextrose agar slants of different pH values had shown that 6.6. was the most favorable pH for the growth of this fungus on this medium under the usual laboratory conditions. For this reason the pH of the agar was adjusted by the colorimetric method to 6.6. The agar was sterilized in an autoclave at 15 pounds pressure for 20 minutes.

A Cooper-Hewitt mercury arc lamp operating at 7.5 amperes and 110 volts served as a source of ultra-violet radiation. The lamp was allowed to run for at least 30 minutes before each experiment so that the intensity of the radiation was fairly constant. The full spectrum of the lamp was employed. In this paper unless it is otherwise stated reference to ultra-violet so far as it is used experimentally includes some infra-red and some visible radiation. This liberty is taken with the assumption that lethal effects are due, as the extensive literature seems to indicate, to energy in the ultra-violet exclusively or practically so.

During irradiation the Petri dishes containing the spores were kept uncovered in a bath whose temperature was controlled to within 0.5°C. by a thermo-regulator. The bath was kept at 0, 10, 20, 30, 40 or 50°C. during irradiation. The Petri dishes were placed one at a time on a small metal table in the bath directly under the center of the lamp. In this way all the spores received approximately the same intensity of radiation. The distance between the lamp and the culture was 40 cm. It was found by means of a thermocouple placed on the surface of the agar in a Petri dish that less than 1.5 minutes are necessary for the agar to reach the temperature of the bath. The time necessary to produce a deflection on a galvanometer equivalent to the number of degrees difference between room and bath temperatures was always found to be appreciably less than 1.5 minutes. For this reason all Petri dishes were allowed to remain in the bath for 1.5 minutes before they were irradiated to make certain that the spores had reached the temperature of the bath.

The spores were exposed for 15, 30, 45 or 60 seconds to ultra-violet radiation, i.e., to the full spectrum of the mercury vapor lamp. Control dishes were left in the bath for 2.5 minutes so that they received a temperature treatment equivalent to that received by the spores which were irradiated for the longest period of time.

After irradiation the dishes were left at room temperature for at least 72 hours or until the spores had formed visible colonies. The time required for germination was longer after long exposures to radiation. The higher

temperatures also retarded germination. The colonies were counted, and the number of colonies was considered a measure of spore germination.

Certain preliminary experiments should be discussed to show the need or lack of need for certain precautions in the procedure. The age of the stock cultures from which suspensions were made apparently had no effect on the results obtained. Spores exposed for 12 hours to 0°C. reacted much more uniformly to radiation than spores not thus precooled. Data obtained from untreated spores were irregular and different experiments gave very different results. Experiments were made to determine, if possible, why cold treatment produced such effects. Agar plates were inoculated with 1 cc. samples from a spore suspension before and after the suspension had been treated with cold. Fewer colonies were formed from precooled spores. The spores most sensitive to cold had been killed. This fact alone, however, does not account for the leveling action of cold. The nature of the effect remains unknown. One further precaution which was deemed advisable was the use of a controlled temperature bath. Becquerel (1910) found that temperature exerts a marked effect on the susceptibility of fungus spores to ultra-violet radiation. He reported that spores of *Aspergillus niger*, *Sterigmatocystis*, and various Mucors, which without temperature control were killed in 2 to 3 minutes, resisted irradiation for 45 minutes at the temperature of liquid air. This raised the question as to what would be the effect of small temperature changes within a sub-lethal range on the reaction of *Fusarium* spores to ultra-violet.

Certain sources of error were found inherent in the procedure, and these could be minimized but never completely eliminated by careful technique. It is impossible to measure so carefully the volume of a spore suspension or to have the spores so evenly distributed in that suspension that each Petri dish will contain exactly the same number of spores. It is also impossible to determine accurately how many of those spores germinate, since the colonies are not always separate and some of the spores do not germinate until others have already formed large colonies. Theoretically, however, the percentage of spores which germinate late should be approximately the same in each Petri dish.

DATA AND RESULTS

Two types of curves commonly appear in the literature representing the death rates of organisms when the percentage of survivors is plotted as a function of the exposure to the lethal agent. In the more recent literature logarithmic curves have fallen somewhat into disrepute and the sigmoid curve is commonly thought of as the curve representing lethal rates.

Table 1 shows the effects of different exposures to ultra-violet radiation on the percentage germination of *Fusarium* spores at 0, 10, 20, 30, 40 and 50° C. The spores were kept at these temperatures only during irradiation. Following irradiation they were kept at room temperature. The germina-

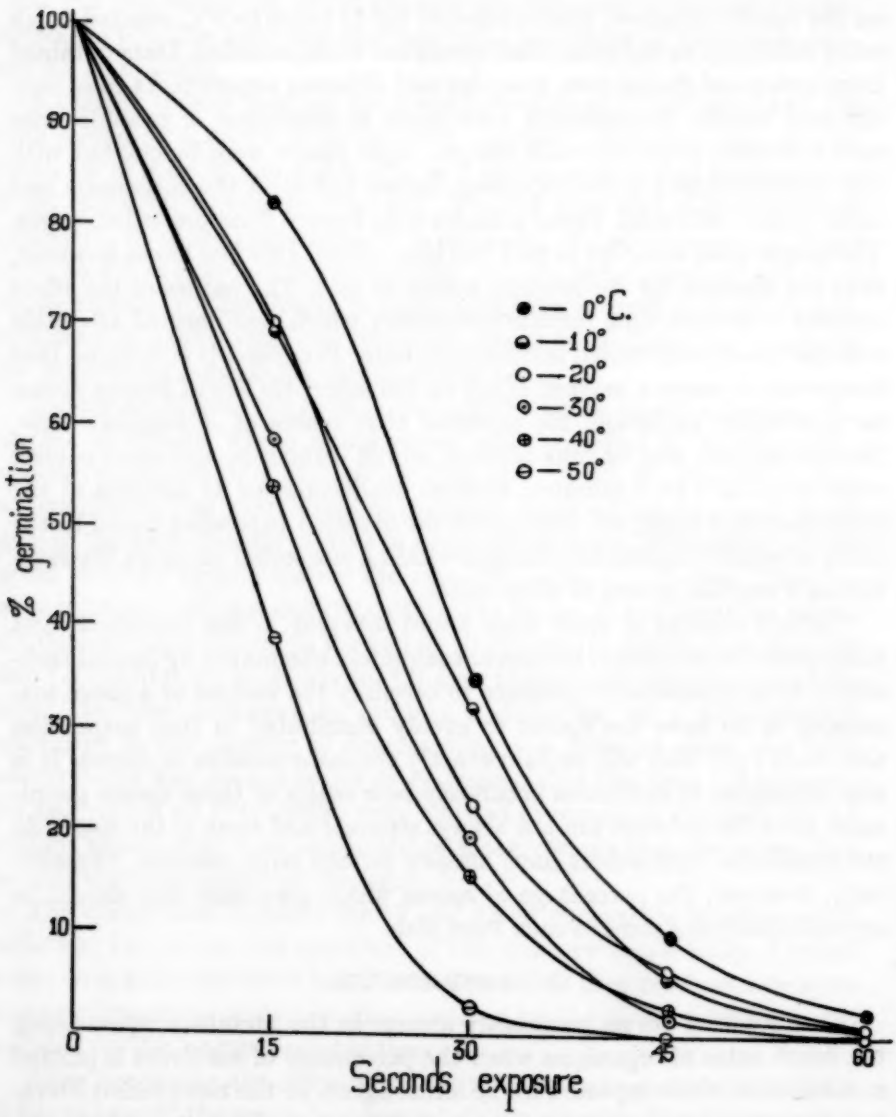

Fig. 1. The average survival of *Fusarium* spores exposed at different temperatures to ultra-violet radiation.

TABLE 1

The values given under the various exposure intervals represent average germination percentages.

TEMPERATURE, °C.	EXPOSURE IN SECONDS			
	15	30	45	60
0	80.5	35.1	9.1	2.1
10	69.3	32.3	5.5	0.6
20	72.2	22.6	6.4	0.9
30	58.6	19.2	1.4	0.0
40	53.9	15.4	2.7	0.8
50	39.1	2.9	0.0	0.1

tion of the controls is considered as 100 per cent. The table is a summary of the data from 11 experiments. An average of 60 dishes was used for an experiment and each dish contained approximately 140 spores. The results are represented graphically in figure 1. With ultra-violet as with most lethal agents deleterious action increases with a rise in temperature. The course of the lethal action follows a sigmoid curve; in other words, there is an initial period during which the death rate lags before its maximum velocity is reached. Beyond this period of maximum velocity the rate again lags and a correspondingly longer time is required to kill the remaining spores. The process of killing falls into two stages, a stage in which progressively larger numbers of spores are killed and a stage in which progressively smaller numbers of spores are killed in each unit of time. As the temperature is increased the curve tends to flatten at the upper bend and approach more and more the logarithmic type. At 50°C. the curve is essentially logarithmic. Table 2 gives the times required to kill 25 or 50

TABLE 2

The values given indicate the times necessary to kill 25 or 50 per cent of the spores at various temperatures when the time to kill 75 per cent is expressed as unity.

TEMPERATURE, °C.	25%	50%	75%
0	0.48	0.72	1.0
10	0.38	0.68	1.0
20	0.48	0.73	1.0
30	0.34	0.63	1.0
40	0.33	0.66	1.0
50	0.28	0.61	1.0
Logarithmic curve	0.20	0.50	1.0

per cent of the spores at different temperatures when the time to kill 75 per cent is expressed as unity. The times which would be required if the

curves were logarithmic are given at the bottom of the table. The observed values approximate more and more closely the logarithmic type the higher the temperature used. Table 3 is similar to table 2 except that the

TABLE 3

The values given indicate the times in seconds necessary to kill 25, 50 or 75 per cent of the spores at various temperatures. The values in parentheses indicate the times necessary when the values at 50° are taken as unity.

TEMPERATURE, °C.	25%	50%	75%
0	16.87 (3.0)	25.12 (2.0)	34.50 (1.7)
10	12.75 (2.2)	22.50 (1.8)	33.00 (1.6)
20	13.87 (2.4)	21.00 (1.7)	28.50 (1.4)
30	9.37 (1.6)	17.25 (1.4)	27.00 (1.3)
40	8.25 (1.4)	16.50 (1.3)	24.75 (1.2)
50	5.62 (1.0)	12.00 (1.0)	19.50 (1.0)

time required to kill 75 per cent of the spores is not expressed as unity. The figures in parentheses are calculated with the values at 50° taken as unity. The times required fall steadily as the temperature is increased. It takes 3 times as long to kill 25 per cent of the spores at 0°C. as it does at 50°C. As the temperature is increased the death rate increases more rapidly in the upper part of the curve than in the lower part and thus tends to reduce the sigmoid character.

A somewhat similar experiment was performed by Gates (1929) with ultra-violet light on bacteria. He found that when he irradiated *Staphylococcus aureus* with 2540Å at 5, 21 and 36°C. deleterious action increased with a rise in temperature and that the curves were all sigmoid.

The question arises as to the possible significance of lethal curves. Rahn (1929) stated that "the order of death is not a function of the killing agent but a property of the organism since so many different agents produce similar curves". J. H. Smith (1921) obtained curves showing the action of various concentrations of phenol on *Botrytis* spores, which resemble very closely the curves described here. On the other hand, curves in which he substituted heat for phenol show no tendency to approach the logarithmic type (Smith, 1923). This strongly suggests that all killing agents do not act alike and that in at least some respects the action of ultra-violet radiation on spores at different temperatures is more like the action of phenol than that of heat. Smith was able to obtain true logarithmic curves if he used young spores, which he found are more sensitive than older ones to low concentrations of phenol. Thus both logarithmic and sigmoid curves are characteristic of death rates. It is somewhat surprising

that such a wide variety of lethal agents as have been employed (heat, chemicals, ultra-violet, etc.) should produce death rates which correspond to one of these two types of curves. Rahn's statement that "the order of death is not a function of the killing agent" holds in some measure. With curves such as those of Smith with phenol and those presented here, the idea of the logarithmic and sigmoid types as something distinct gives way to the conception of a gradual transition between them.

The logarithmic type of curve is characteristic of monomolecular reactions, and consequently it has been considered by those favoring the logarithmic curve that death results from some type of monomolecular reaction. Those who favor the sigmoid type have attributed the character of the curve to chance variation in resistance. These two somewhat opposing views have been fully reviewed and defended by Brooks (1906) and by Cohen (1922). A symmetrical sigmoid curve, when transformed, becomes a normal frequency curve such as would result from chance variation. It seems unlikely that some entirely different factor should be responsible for the logarithmic curve, and the possibility exists that the resemblance between the logarithmic lethal curve and the monomolecular curve is entirely fortuitous. The resemblance likewise between the normal frequency curve and the similar curve obtained from the sigmoid type may, of course, also be fortuitous. It has been suggested that if the latter is the case the logarithmic is the typical death rate curve, and that while departures from it may be due to individual variation the fundamental nature of the curve is due to something quite different, perhaps to the fact that death is characterized by some monomolecular reaction. The other course which is open, and which seems to the author as involving less speculation, is that the fundamental nature of the curve is due to individual chance variation and is therefore sigmoid in shape. The logarithmic curve results only when the treatment is so rigorous that all of the more sensitive individuals die almost instantaneously, at least so rapidly that measurements are not sufficiently fine to detect any differences in resistance. Carrying this idea still further it is easy to conceive of a treatment so promptly lethal that all of the spores would be killed before any intermediate stages could be detected. The logarithmic curve is merely a sigmoid curve with the upper part very much flattened. Table 3 shows that with high temperatures the time of killing is much more reduced in the early part of the process than in the later stages. This would not necessarily be the case with high intensities of all types of killing agents, so that the logarithmic curve is not always characteristic of strong lethal action.

Many experiments made by others have shown that the effects of exposures to ultra-violet radiation are usually additive. For example, 2 one-

minute exposures to "x" intensity produce the same effect as 1 one-minute exposure to "2x" intensity. The total effect may depend, as it does in many photochemical phenomena in the purely physical world, on the total number of light quanta which are absorbed by the individual. If this is true then any particular spore will die when the necessary number of quanta of ultra-violet radiation have been absorbed. The time can be reduced by increasing the intensity or by decreasing the resistance of the spore. In the experiments described here the resistance was decreased by increasing the temperature.

By way of summary, the death rates of *Fusarium* spores exposed to ultra-violet radiation at different temperatures take the form of sigmoid curves which rapidly approach the logarithmic type as the temperature is increased. Deleterious action increases with a rise in temperature. As the temperature is increased the death-rate increases more rapidly in the upper part of the curve than in the lower part. The significance of such curves is still somewhat obscure, but it seems probable that chance variation in resistance to the lethal agent is responsible for the shape of the curves. Those curves which approach the logarithmic type are merely modified sigmoid curves in which the lethal rate has increased most for the least resistant spores. A rise in temperature increases spore sensitivity, and there is also the possibility that temperature may sometimes act as a lethal agent in conjunction with ultra-violet radiation.

TEMPERATURE COEFFICIENTS

The use of temperature coefficients often gives the biologist some insight or clue to the nature of the reaction which he is studying. The question immediately arises as to whether the reaction which manifests itself in the sigmoid lethal curve is primarily of a physical or chemical nature. A temperature coefficient is defined here as the ratio of the times required to reach a constant result with a 10° rise in temperature. Table 4 gives temperature coefficients calculated for different portions of the lethal curves presented in figure 1. Since the 10° and 20° curves cross, probably because the technique is not sufficiently accurate to separate the two curves, some blanks appear in the table. These coefficients would be negative if calculated, and since such coefficients are unlikely to occur it is assumed that they are incorrect. The rest of the values, however, are quite constant. The average temperature coefficient for 0 to 40° is 1.13 and for 40 to 50° is 1.37. These temperature coefficients are characteristic of a physical or photochemical reaction rather than of a purely chemical reaction. This suggests that death may be a direct result following the absorption of energy.

These temperature coefficients are in quite close agreement with the temperature coefficient of 1.05 obtained by Bayne-Jones and Van der Lingen (1923) for bacteria exposed to the total radiation of a zinc spark and also to that of 1.09 obtained by Gates (1929) for *Staphylococcus aureus* exposed to 2540Å. They differ markedly from those of J. H. Smith (1923) for the action of heat on *Botrytis* spores. He obtained values ranging from 29.5 to 690.0, the highest temperature coefficient being representative of

TABLE 4

Temperature coefficients calculated for different portions of the lethal curves.

PERCENTAGE KILLED	SECONDS REQUIRED TO KILL						TEMPERATURE COEFFICIENTS				
	DEGREES C.						DEGREES C.				
	0	10	20	30	40	50	0–10	10–20	20–30	30–40	40–50
10	9.0	6.7	5.6	4.4	3.1	2.0	1.33	1.20	1.27	1.38	1.54
20	15.0	9.9	11.6	7.5	6.5	4.5				1.14	1.45
30	18.7	14.6	15.7	11.2	9.7	6.7				1.15	1.44
40	21.7	18.7	18.1	14.6	12.9	9.3	1.16	1.03	1.24	1.13	1.37
50	25.1	22.5	20.8	17.6	16.3	12.0	1.11	1.07	1.18	1.07	1.36
60	28.3	26.6	23.6	20.4	18.7	14.8	1.06	1.12	1.15	1.08	1.26
70	32.2	30.7	26.8	24.3	22.5	18.0	1.04	1.14	1.10	1.08	1.25
80	37.3	35.2	31.8	29.2	27.3	21.0	1.05	1.10	1.08	1.06	1.30
							1.12	1.11	1.17	1.13	1.37 Av.

the lowest temperature. If a high temperature coefficient, which Smith has demonstrated to be characteristic of a heat effect, is due to a heat effect here, then this study of temperature coefficients may show that between 40 and 50°C. temperature acts not merely as a sensitizer but also as a lethal agent in conjunction with ultra-violet radiation.

TEMPERATURE EFFECTS

In order to study the effects of sudden changes of temperature on *Fusarium* spores sterile glass capillaries approximately 1 to 1.5 millimeters in diameter and 7 to 8 inches in length were partially filled with a heavy spore suspension and sealed in an alcohol flame. The capillaries were weighed before and after filling to determine the weight of the spore suspension in each capillary. The capillaries were then immersed in a bath at temperatures ranging from 0 to 52°C. for periods of 30 seconds to 10 minutes. Duggar[1] found by use of a small thermo couple that solutions contained in glass capillaries of these dimensions reach the temperature of the bath almost instantaneously. By the use of this method the spore suspension can be brought to any desired temperature without an ap-

[1] Duggart, B. M. (*Inedit.*) Determination of inactivation temperatures with plant viruses.

preciable time-lag. After exposure the capillaries were immersed immediately in dilute hydrochloric acid at room temperature. This brings the spore suspension quickly back to room temperature and also kills bacteria which may be present on the outside of the capillaries. Then, under the protection of a sterile transfer chamber, the ends of the capillaries were broken and the spore suspension from each was plated out separately on agar prepared as before. One cubic centimeter of sterile distilled water was added to each Petri dish so that the spores might be spread more uniformly over the agar. Colony counts were made after about 72 hours, and the number of colonies was considered a measure of spore germination. The percentage germination was calculated by comparing each germination with that calculated for an equal weight of a control suspension. The method outlined here is tedious, contaminations frequently occur, and spores adhering to the inner walls of the capillaries introduce a rather large source of error. In any one experiment, however, repetitions of any particular temperature treatment gave fairly constant results, but repetitions of the experiment with a different spore suspension gave widely different results. This was true even if precautions were taken to use spores of approximately the same age and to have all other conditions as nearly uniform as possible.

The only conclusions which can be drawn are that the spores are extremely variable in their response to sudden changes of temperature and apparently very slight variations in previous environment have much to do with their behavior. With temperatures above 48°C. there is always some lethal action which increases rapidly with slight increases in temperature.

A study was also made of the effects of temperature changes on spores plated on potato-dextrose agar. The plates were placed in a bath at 0, 10, 20, 30, 40 and 50°C. for 2.5 minutes. It requires approximately 1.5 minutes for the spores to reach the temperature of the bath whereas the change in temperature is almost instantaneous when the spores are in capillaries. But here again the results are just as variable. In one experiment the number of spores which germinated continually increased with an increase in temperature. In another it continually decreased, while in others the maximum germination occurred at some intermediate temperature.

The action of temperature alone must not be confused with its action in conjunction with ultra-violet radiation. The two are strikingly different. In the study of the lethal effects of ultra-violet on spores irradiated at different temperatures the values which were used to calculate the averages indicated in table 1 never varied more than 10 per cent despite the fact that no attention was given to the age of the spores used.

SENSITIVITY

The mycelium of fungi is in general more sensitive to ultra-violet radiation than the spores. To study the relative sensitivity of the spores and mycelium of *Fusarium* to ultra-violet radiation the spores were placed in sterile distilled water and 1 cc. samples of the suspension were plated out on agar prepared as for the study of lethal action. Once every hour 5 to 10 plates were exposed to ultra-violet at 0°C. at 40 cm. from the lamp. To study the effects of radiation on spores and mycelium in different stages of development it was necessary to use several spore suspensions made at different times preceding irradiation. Because of the nature of the experiment the precooling treatment employed in other phases of this work had to be omitted. This resulted in much more variable results than were obtained in the study of lethal action. The exposure was for 15 seconds in experiment 1 and for 30 seconds in experiments 2, 3 and 4. Approximately

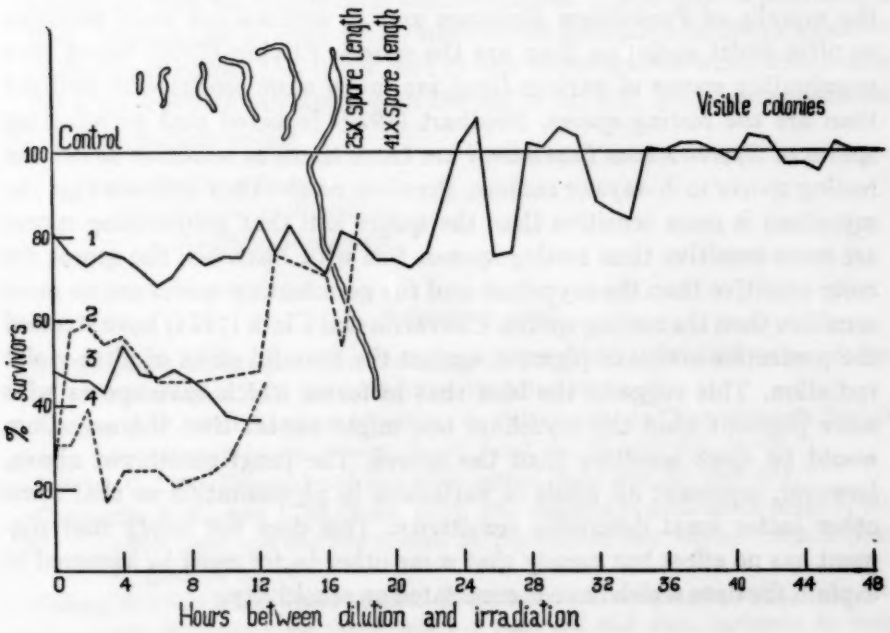

Fig. 2. The relative sensitivity of the mycelium and spores of *Fusarium* to ultra-violet at 0°C. After a suspension was made the spores were irradiated at one hour intervals. The different stages of development at the time of irradiation are indicated above their proper horizontal coordinates.

72 hours after the suspension was made the colonies were counted. The results are shown graphically in figure 2 with the number of hours between

dilution and exposure plotted against the percentage of survivors. During the course of the experiments camera lucida drawings were made of the spores and mycelium at various stages of development and these are reproduced in the graph above their proper horizontal coordinates. The spores germinated at approximately the same time in all four experiments. Experiment 1 was designed to show the relation between the sensitivity of the mycelium and the spores. While a 15-second exposure kills about 20 per cent of the spores it has little to no effect on the mycelium. In other words, the spores are more sensitive than the mycelium to ultra-violet radiation. This experiment also suggests that the germinating spore is no more sensitive than the resting spore. Experiments 2, 3 and 4 verify this suggestion. Both of these results are, in general, contradictory to those which have previously been reported for fungi. Schulze (1909) reported that the mycelium of *Mucor stolonifer* is more sensitive than the spores to ultra-violet radiation of 2800Å. Fulton and Coblentz (1929) found that the mycelia of *Penicillium digitatum* and *P. italicum* are more sensitive to ultra-violet radiation than are the spores. Elfving (1890) found that germinating spores of various fungi are much more sensitive to sunlight than are the resting spores. Neidhart (1924) reported that germinating spores of *Sporotrichum Beurmanni* are three times as sensitive as are the resting spores to X-rays or radium. Previous results then indicate that the mycelium is more sensitive than the spores and that germinating spores are more sensitive than resting spores. But with *Fusarium* the spores are more sensitive than the mycelium and the germinating spores are no more sensitive than the resting spores. Chavarria and Clark (1924) have stressed the protective action of pigment against the harmful effect of ultra-violet radiation. This suggests the idea that in forms which have spores with more pigment than the mycelium one might expect that the mycelium would be more sensitive than the spores. The fungi mentioned above, however, represent all kinds of variations in pigmentation so that some other factor must determine sensitivity. This does not imply that pigment has no effect but merely that some other factor must be assumed to explain the data which have accumulated on sensitivity.

SUMMARY

1. The death rates of *Fusarium* spores exposed to ultra-violet radiation at different temperatures take the form of sigmoid curves which rapidly approach the logarithmic type as the temperature is increased. Deleterious action increases with a rise in temperature. The theory is advanced that sigmoid curves are due to chance variation in resistance to the lethal

agent and that logarithmic curves are merely modified sigmoid curves in which the death rate has increased most for the least resistant spores.

2. The average temperature coefficient between 0 and 40°C. is 1.13 and between 40 and 50°C. it is 1.37. These coefficients are characteristic of a physical or photochemical reaction. The higher temperature coefficient between 40 and 50°C. may indicate that temperature has not merely a sensitizing effect but also a lethal effect in conjunction with ultra-violet radiation.

3. The effects of temperature are variable in the absence of ultra-violet radiation but relatively constant in the presence of it.

4. The mycelium of the fungus used is less sensitive to ultra-violet than the spores, and germinating spores are no more sensitive than resting spores.

This investigation was proposed by Prof. B. M. Duggar and has been carried on with his suggestions and criticisms. The author is indebted to Prof. Duggar and to Prof. H. H. Bartlett for assistance in the preparation of the manuscript. The latter part of this investigation was carried on at the University of Michigan with the aid of an F.C. and Susan Eastman Newcombe Fellowship.

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INDEX TO AMERICAN BOTANICAL LITERATURE
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The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

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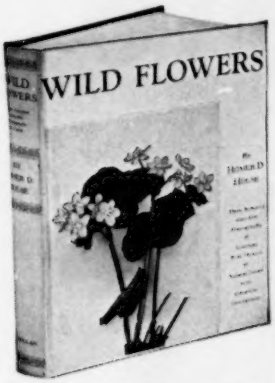

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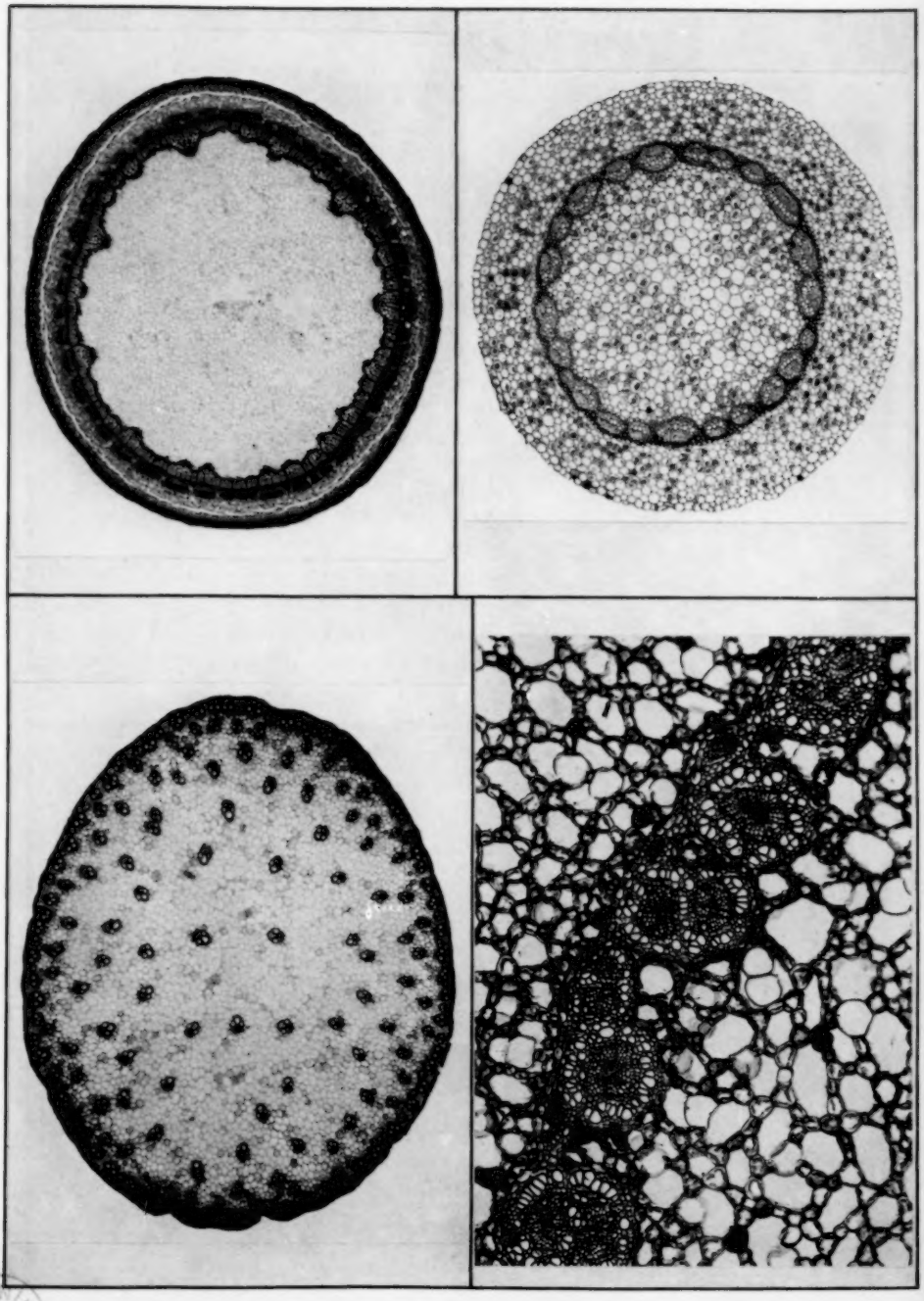

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